

DISSERTATION

1817

ELECTIVE ATTRACTIONS.

By TORBERN BERGMANN.

LATE PROFESSOR OF CHEMISTRY AT UPSAL, AND
KNIGHT OF THE ROYAL ORDER OF VASA.

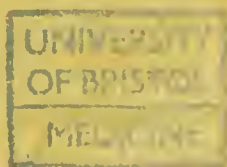
Translated from the Latin by the TRANSLATOR
OF SPALLANZANI'S DISSERTATIONS.

(Thomas Beddoes)

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P R E F A C E.

THE usefulness of publications, which; like the present Dissertation, exhibit, from time to time, comprehensive views of scientific knowledge, has been sufficiently pointed out by Lord BACON, whose dictates upon this subject, as upon others, have been amply confirmed by experience. The Translator, therefore, at first thought, that every purpose of the English reader would be abundantly served by a faithful translation of this admirable manual of theoretical Chemistry. His duty plainly forbid him to alter or suppress any thing; and his reverence for the great author deterred him from the thought of making any addition. But some time has elapsed since the task of

mere translation was completed ; in the mean time, chemical investigation being continued with universal ardour, new facts were brought to light, and new theories proposed, some of them in books not likely to fall into the hands of every reader. Hence it seemed almost a matter of necessity to add some annotations. The Translator now wishes, for the convenience of the reader, that they had been subjoined to the pages to which they refer, though, for his own sake, he is not sorry that they are thrown back as far as possible. This accidental circumstance of their situation has led him to be more diffuse than he would otherwise have been. The notes could not, by their intrusion on the reader's eye, divert his attention from the author ; and why should any thing which was useful, and perhaps

perhaps inaccessible to many, be withheld, when it had any connection with the subject?

Two sets of Tables are subjoined. It was thought that many readers would be dissatisfied with the chemical Characters alone, especially as the former edition of the Tables has been already published in words. To suppress the signs entirely, seemed improper; for they are so convenient, that every student of chemistry ought to make himself familiar with them. Besides, as most Chemists will wish for a set to stand always open for inspection, the two sets will scarce be thought superfluous by any.

EVERY man who delights in paying the respect that is due to genius, learning,

ing,

ing, and industry, will hear with pleasure, that the life of our consummate philosopher has been promised us by his excellent friend, Mr Scheele. The following testimony of regret, on account of his premature death, appeared soon after that event; an event which those who, by comparing what he did for chemistry with the short time during which he applied to it, shall become sensible of what he would have accomplished in a long life, can alone adequately lament.

Pertristem

Pertristem adferre nuncium oportet,
 Post exactos mortali vita annos XLIX,
 Ereptum esse Patriæ,
 Cultiori orbi, bonorumque omnium amplexibus,
 VIRUM longè CELEBRATISSIMUM,

TORBERNUM BERGMANN.

CHEM. METALLURG. ET PHARMACEUT. IN
 ACADEM. UPSALIENSI PROFESSOREM ;
 EQUITEM AURATUM REG. ORD. DE WASA ;
 ACAD. IMP. N. C. ; REGIARUM ACADEMIARUM
 ET SOCIETATUM PARIS, MEDICÆ PARIS.
 MONTISPESS. DIVIONENS. UPSAL.
 STOCKH. UTRIUSQUE LONDIN. GOETTING.
 BEROLIN. TAURIN. GOTHOBURG. LUND,
 SODALEM.

Id quod accidit d. viii. Julii anni 1784,
 Dum ad acidulas Medvicenses, in Ostrogothia,
 Afflictæ dudum valetudini quærebatur solatium,
 Lugent per universam Suecogothiam
 Optimarum scientiarum Patroni et Cultores ;
 Necdum inveniunt
 Quem tanti viri desiderio modum ponant.
 Superstitibus, autem, cognatis et amicis,
 Hoc denique lacrimabile officium relictum est,
 Ut, mœstissimæ nomine viduæ,
 Fautores in exteris gentibus et Consortes studiorum,
 Quæ naturalis omnis scientiæ vir peritissimus
 Excoluit,
 De communi clade certiores faciant,
 Proque suâ adeo agant parte,
 Ut justissimi luctus æquè latè sentiatur pietas,
 Ac BERGMANNIORUM existimatio meritorum
 Jam diu inclaruit.

UPSALIÆ d. xvi. Julii }
 1784. }

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DISSERTATION, &c.

Jamne vides igitur magni primordia rerum
Referre, in quali sint ordine quæque locata,
Et commissa quibus dent motus accipiantque.

LUCRETIVS.

THIS Dissertation was first printed in 1775, in the third volume of the New Upsal Transactions. It was afterwards translated both into German and French. The two annexed Tables, which exhibit the single and double attractions, were again engraved in London, by the care of Dr Saunders, for the use of those who attended the lectures which he read in conjunction with Dr Keir. The same year, Mr More, secretary to the Society for the Encouragement of Arts and Manufactures, published the table of elective attractions, on a large sheet, substituting English words in the place of the signs.

O Ñ

though the mode of agency be as yet unknown.

It has been shewn by Newton, that the great bodies of the universe exert this power directly as their masses, and inversely as the squares of their distances. But the tendency to union which is observed in all neighbouring bodies on the surface of the earth, and which may be called *contiguous attraction*, since it only affects small particles, and scarce reaches beyond contact, whereas remote attraction extends to the great masses of matter in the immensity of space, seems to be regulated by very different laws; it seems, I say, for the whole difference may perhaps depend on circumstances. Considering the vast distance, we may neglect the diameters, and look upon the heavenly bodies, in most cases, as gravitating points. But contiguous bodies are to be regarded in a very different light; for the figure and situation,

situation, not of the whole only, but of the parts, produce a great variation in the effects of attraction. Hence quantities, which in distant attractions might be neglected, modify the law of contiguous attraction in a considerable degree; and, moreover, the great power of our globe on all occasions influences and disturbs it. This force may therefore produce wonderful variations in the effects, according to circumstances. But as we are by no means able to ascertain the figure and position of the particles, it remains that we determine the mutual relations of bodies with respect to attraction in each particular case, by experiments properly conducted, and in sufficient number.

As contiguous attraction scarce extends beyond contact, it is obvious, that the former will be more intense in the same body, the more the latter is increased. Hence, in the following ob-

A 2 servations,

servations, many instances occur, which prove that a body has greater power in a liquid than in a solid state, and still greater when it is resolved into vapour. See, in particular, what is said of marine acid, with respect to phlogiston, in the forty-seventh paragraph; and of the matter of heat, in the forty-eighth.

IN this dissertation, I shall endeavour to determine the order of attractions according to their respective force; but a more accurate measure of each, which might be expressed in numbers, and which would throw great light on the whole of this doctrine, is as yet a desideratum *.

SEVERAL

* Mr Morveau, I believe, first determined and expressed in numbers the cohesion of quicksilver to some of the metals. Mr Achard afterwards published a large table, in which the cohesive force of many bodies is investigated both by calculation and experiment. Mr Kirwan very lately

SEVERAL species of contiguous attraction may be distinguished. I shall here briefly mention the principal. When homogeneous bodies tend to union, an increase of mass only takes place, the nature of the body remaining still the same; and this effect is denominated *the attraction of aggregation*. But heterogeneous substances, when mixed together, and left to themselves to form combinations, are influenced by difference of quality rather than of quantity. This we call *attraction of composition*; and when it is exerted in forming a mere union of two or more substances, it receives the name of *attraction of solution or fusion*, according as it is effected either in the moist or the dry way. When it takes place between three respectively, to the exclusion of one, it is said to be a *single*

A 3

elective

lately began to measure the attractions, by the diminution of bulk that is produced by union; for he is of opinion, that the cause and quantity of contraction is to be sought in the force of attraction.

elective attraction ; when between two compounds, each consisting of only two proximate principles, which are exchanged in consequence of mixture, it is intitled *double attraction*. I am particularly to consider the two last species.

II.

Single Elective Attractions.

SUPPOSE A to be a substance for which other heterogeneous substances a, b, c , &c. have an attraction ; suppose, further, A , combined with c to saturation, (this union I shall call Ac), should, upon the addition of b , tend to unite with it to the exclusion of c , A is then said to attract b more strongly than c , or to have a stronger elective attraction for it ; lastly, let the union of Ab , on the addition of a , be broken, let b be rejected, and a chosen in its place, it will follow, that a exceeds b in attractive power,

and

and we shall have a series, *a, b, c*, in respect of efficacy. What I here call attraction, others denominate affinity ; I shall employ both terms promiscuously in the sequel, though the latter, being more metaphorical, would seem less proper in philosophy.

GEOFFROY, in 1718, first exhibited at one view the series of elective attractions, by arranging in a table the chemical signs, according to a certain order ; but this admirable contrivance, while it is commended by some, is blamed by others ; one party contending, that affinities are governed by fixed laws, and the other affirming, that they are vague, and to be ascribed to circumstances alone.

Now, since all chemical operations consist either in analysis or synthesis, composition or decomposition, and both the one and the other depend on attraction,

tion, it will certainly be of great importance to determine this dispute. Let us not then lightly, and on account of one or two irregularities, perhaps ill understood, reject the whole doctrine, but let us rather proceed in our examination with caution and care. Should we even at last find that attractions depend on circumstances, shall we therefore conclude, that it will be useless to know the several conditions that forward or impede or disturb them? By no means, but rather that it will be of extensive utility. There does not exist in all nature a single phænomenon but what is so connected with certain conditions, that when they are absent, the phænomenon shall either not appear, or be varied occasionally. It is of consequence to science, that the changes and the combination of causes in every operation should be accurately known, as far as a knowledge of them
is

is attainable ; and the utility of a strict inquiry into attractions will, I hope, clearly appear from many instances in the following pages.

BUT if, on the contrary, a fixed order does really take place, will it not, when once ascertained by experience, serve as a key to unlock the innermost sanctuaries of nature, and to solve the most difficult problems, whether analytical or synthetical ? I maintain, therefore, not only that the doctrine deserves to be cultivated, but that the whole of chemistry rests upon it, as upon a solid foundation, at least if we wish to have the science in a rational form, and that each circumstance of its operations should be clearly and justly explained. Let him who doubts of this consider the following observations without prejudice, and bring them to the test of experiment.

III.

Whether the Order of Attractions be constant.

THIS question can only be properly answered from what follows. But let us now slightly consider whether a constant series, such as is mentioned in the last paragraph, is to be expected. Does a expel b , and b a reciprocally, according to circumstances? Does c perchance expel a , while it always gives way to b ? Let us consult Experiment, the oracle of nature, with due care and patience, and we shall doubtless find the proper clue to guide us out of this labyrinth.

I AM far from approving of those general rules which affirm, that earths and metals are in all cases precipitated by alkalis, and metals by earths, for they are often fallacious. We have, however, many particular observations, which,

which, when every thing is properly disposed, never mislead. We know, for instance, that volatile alkali is dislodged by fixed alkali and pure calcareous earth; that quicksilver and silver are precipitated from nitrous and vitriolic acids on the addition of copper, which is again separated by iron. Silver, quicksilver, and lead, which were called the white metals by the ancients, are separated from the nitrous acid both by the vitriolic and marine. Do not these, and other facts long since known, shew, that there prevails a constant order among these several substances? Many other clear proofs occur in the explanation of the new table of attractions, which I shall reserve for their proper places, (XII.—LXX.). The difficulties, when closely examined, disappear; and none has yet, as far as I know, been pointed out which is really inconsistent with a continued series. But should there occur in this, as in other branches
of

of natural philosophy, a few phænomena, which appear to deviate from the ordinary track, they should be considered as comets, of which the orbits cannot yet be determined, because they have not been sufficiently observed. Repeated observations, and proper experiments, will in time dispel the darknesses.

THAT the effect of three substances mixed together may appear at one view, I have contrived a way of representing it by symbols. It will be proper to illustrate it by an example.

SCHEME 20. Pl. I. exhibits the decomposition of calcareous hepar by the vitriolic acid. On the left side appears the hepar, indicated by the signs of its proximate principles united; but within the vertical bracket these principles are seen separate, one above the other. On the right, opposite the calcareous earth,

earth, is placed the sign of vitriolic acid; in the middle stands the sign of water, intimating that the three surrounding bodies freely exercise their attractive powers in it. Now, as vitriolic acid attracts calcareous earth more forcibly than sulphur does, it destroys the composition of the hepar; the extruded sulphur being by itself insoluble falls to the bottom, which is signified by the point of the lower horizontal half-bracket being turned downwards; and as the new compound, vitriolated calcareous earth (gypsum), also subsides, unless the quantity of water be very large, the point of the upper bracket is likewise turned downwards. The complete horizontal bracket indicates a new combination, but the half-bracket serves merely to shew by its point whether the substance from which it is drawn remains in the liquor, or falls to the bottom. The absence of horizontal brackets indicates that the original compound

compound remains entire. Such a combination only as continues unaltered can have a place on the right side, for if it be likewise decomposed, a new case arises, which will be noticed hereafter, (V.). Those operations which are performed in the dry way, are distinguished by the character of fire, which is placed in the middle.

IV.

A Difference in the Degree of Heat sometimes produces a Difference in Elective Attractions.

THE only external condition, which either weakens or totally inverts the affinities of bodies subjected to experiments, is the different intensity of heat. But this cause can only operate in cases where the same temperature renders
some

some bodies remarkably volatile in comparison of others.

SUPPOSE A to be attracted by two other substances; and let the more powerful act at the ordinary temperature with the force a , the weaker with the force b : suppose, at the same time, the former to be the more volatile; let its effort to arise be expressed by V , and that of the other by v . When these three substances are mixed together, the stronger will attract A with a force $=a-b$; but should the heat be gradually raised, this superior force will be more and more diminished; and as V will increase faster than v , we shall at last have $a-b=V-v$. This state of equilibrium will be immediately destroyed by the smallest addition of heat; and thus b , which was before the weaker, and incapable of producing any effect, will now prevail. If the other substance be entirely of a fixed nature, $v=0$, and the

the case will be simpler. Many instances of this nature will hereafter occur.

HENCE, I think it in general obvious, that those are the genuine attractions, which take place when bodies are left to themselves: too high a degree of heat is an external cause, which forcibly weakens the real affinities more or less, nay, in some cases, even totally alters them. Since, however, many operations cannot be carried on without the aid of heat, and the power therefore of this most subtile fluid is highly worthy of being observed, I think the table of elective attractions ought to be divided into two areas; of which the upper may exhibit the free attractions, that take place in the moist way, as the expression is; and the lower, those which are effected by the force of heat. This may easily be done, since we are as yet unacquainted with any other external

ternal condition which deserves here to be taken into the account; if the internal conditions ever cause any deviation, it is either only apparent, or else a real change in the nature of the substances is produced. It cannot indeed be denied, that volatile bodies are actually changed by a combination with the matter of heat; but the change is of short duration, as it totally disappears on refrigeration, though not till after the desired decomposition has been effected.

It is hence evident, what opinion we are to form concerning the various arguments brought against the constancy of affinities, from the distillation, sublimation, or fusion of mixtures: such sometimes is the efficacy of heat, that strong digestion, or even that degree of warmth which is produced by the combination of certain substances, is sufficient to disturb the usual order.

V.

Apparent Irregularities from a double Attraction.

NOTWITHSTANDING the trite proverb, That no rule is without exception, I do not therefore think that rules are to be rejected ; but the exceptions should be properly investigated, and the rules thus be reduced to their just amount. Those, however, which are now to be considered, do not come under the denomination of exceptions ; for four substances exert their action, a very different case, and more complicated, than where three only are concerned. Many instances usually adduced in refutation of a regular series of affinities belong to this head ; and though it is said that reciprocal decomposition is evidently shewn by them, a
closer

closer examination will dissipate the illusion.

GEOFFROY's table intimates, that fixed alkalis adhere to acids more strongly than calcareous earth, and with great propriety, though some would represent this truth as an absurdity. They drop a solution of chalk in nitrous acid into a solution of vitriolated tartar, upon which a precipitation of gypsum immediately takes place; a clear proof, as they think, of the superior attraction of the calcareous earth. But it should be observed, that not even quicklime, when added to a solution of vitriolated tartar, (Scheme 2.), produces any decomposition; but, on the contrary, if vitriolic acid be dropped into the solution of calcareous earth, a precipitation of gypsum will follow, (Scheme 16.): Hence it is obvious to which the stronger elective attraction is to be attributed. When the chalk has been previously dissolved

in some mineral acid, four substances come into action; and now the earth, aided by the acid which is combined with it, effects what before it was not able to accomplish. To render this more evident, let us consider the 21st Scheme, in which, on the left hand, the neutral salt, known by the name of vitriolated tartar, is indicated by the sign of vegetable fixed alkali placed near that of vitriol. I read it in this manner: Vitriolated vegetable alkali, (that is, saturated with the acid obtained from vitriol), a denomination by which the proximate principles are known; and these also appear under their proper signs within the adjacent vertical bracket. On the right, muriated lime (saturated with the marine acid) is likewise represented by symbols, as also its proximate principles within their proper bracket. Whilst therefore vitriolated tartar and lime saturated with the acid of salt are mixed together in water, (which

(which is expressed by the sign of water in the middle of the Scheme), the same thing happens as if we were to mix certain portions of vegetable fixed alkali, vitriolic acid, marine acid, and pure lime in water: these four substances surround water in the figure, and are so to be placed, that the two acids should never be in the same horizontal line.

WE have the substances that were combined before mixture disposed in a vertical position; and, in order to break the combination, there is necessarily required a greater sum of attraction between those which are horizontally, than those which are vertically opposite to each other: and such is the present case; for although the vitriolic acid attracts the fixed alkali more strongly than it does the lime, yet, upon the addition of muriatic acid, which at once solicits the alkali, and diminishes its cohesion with the vitriolic acid, the attraction between

the fixed alkali and the marine acid, together with the attraction between the vitriolic acid and the lime, make together a greater sum than the attraction between the fixed alkali and the vitriolic acid, together with that between the muriatic acid and the lime.

THE horizontal brackets include the new combinations: by the apex of the lower turned downwards, subsidence is denoted; but the apex of the upper pointing upwards, shews that the combination contiguous to it remains in the liquor, until a certain portion be carried off by evaporation. Thus then is the decomposition in question effected. That I may more quickly dispatch the other instances, I shall once for all observe, that I always express double salts (such as consist of two proximate principles) by the sign of the base placed on the left, near the sign of that salt from which the acid is ordinarily expelled,
which

which acid is at present combined with the base: in the same way I design the others, consisting of two principles intimately united.

MAGNESIA, and several of the metals, resemble lime in this respect. See Scheme 22. Table 1. contains sixty-four schemes, which exhibit the events of 122 experiments; for No. 24. not only shews, that nitrated mercury is decomposed by feret sal ammoniac, but also that flaming nitre and vitriol of mercury will bear to be mixed without suffering any change; and, in general, if the substances represented on the right and left side make a mutual exchange of their principles, we may judge that those which stand above and below undergo no separation on mixture. In Schemes 21. and 23. it appears that vitriolated tartar and muriated lime change their principles, but not digestive salt and gypsum. Nos. 1.—20. ex-

hibit the single, 21.—40. the double free attractions. The following are brought about by the accession of fire : 41.—47. and 55.—58. by distillation ; 48.—50. and 59.—62. by sublimation ; and, lastly, 51.—54. 63. and 64. by fusion in a crucible. An explanation of the new characters is found in XI.

CHEMISTS, in determining the single elective attractions, are often deceived by double attractions. The phosphoric acid, as I shall hereafter shew, (XXXIII.), attracts lime more powerfully than fixed alkali ; yet the contrary is asserted, since aerated alkali, by means of a double affinity, precipitates phosphorated lime. Even caustic fixed alkali, which seems a stronger proof, causes a precipitation : nevertheless, if the superior attraction is deduced from this alone, the conclusion will be erroneous ; for the alkali only takes away the excess of acid which is requisite for solution,

tion, and hence the phosphorated lime falls to the bottom; (IX.). The difference between the action of alkalis and absorbent earths, when saturated with aerial acid, and when destitute of it, has been explained in my essay on that acid, and may therefore be omitted here *. What is there said of the volatile alkali, is expressed in Scheme 36. and clearly shews the reason why caustic volatile alkali seems to act more weakly than the mild, which otherwise would be absurd. It may now, in general, be observed, that alkaline and earthy substances are to be considered as double, and by no means as simple salts, except in their caustic state, and then I call them pure. See Schemes 1.—8. 32.—37. 51. 62. and 63.

THE precipitation of metals, dissolved in acids, by other metals, is never the effect of single attraction; for during
the

* Op. vol. i. p. 49.

the solution, a quantity of phlogiston is extricated, as I have clearly, I hope, shewn elsewhere *. Since therefore metallic solutions are of such a nature, that they cannot restore what they hold dissolved to its metallic splendour without the accession of a new portion of phlogiston, it is self-evident, as well as conformable to experiment, that this cannot be effected by the addition of calces. If therefore ochre be put into a solution of vitriol of copper, no copper will be precipitated; but iron added to the solution is soon observed to be covered with a cupreous pellicle; for it yields part of its phlogiston, which is necessary to the reduction of the copper, and by this means becomes itself soluble without the emission of any inflammable air, (Scheme 39.). Silver dissolved in the nitrous acid is in like manner calcined; as appears from the red vapour, phlogistic smell, and various

* Op. vol. ii. p. 354. vol. iii. p. 134.

rious other evident signs, and therefore cannot be precipitated by the calx, though it may by regulus of copper, (Scheme 38.). The same observation is applicable to gold and the other metals; for in whatever way they be separated, provided they can acquire no phlogiston, they appear calcined, and really are so: the only difference consists in this, that they are unequally dephlogisticated, and that the noble metals can recover their loss by fusion alone in ignited vessels, whereas the ignoble ones require an addition of phlogiston. But more of this hereafter.

IN many other cases, where a single elective attraction is commonly thought to take place, it is really double, on account of the presence of phlogiston. Let us consider an instance of this in the distillation of butter of antimony from a mixture of corrosive sublimate and regulus of antimony. We may observe, in the

the first place, that neither mercury nor regulus of antimony are soluble in the marine acid, unless they are first deprived of a certain portion of their inflammable principle. From this consideration, the process is easily explicable from a double attraction: the calx of mercury in corrosive sublimate is revived, by that phlogiston which the regulus must lose in order to become soluble in marine acid, (Scheme 58.). The basis of corrosive sublimate, indeed, as well as the calces of the noble metals, recovers its reguline state in heat alone, by attracting what is wanting to this state, through the ignited vessels; but this operation requires a far stronger fire than the distillation of butter of antimony, in which the reduced mercury rises without any very strong heat. With white arsenic and corrosive sublimate no decomposition is effected, since the phlogiston necessary for the reduction of the mercury is wanting; but
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this operation succeeds with orpiment, which abounds with phlogiston.

VI.

Apparent Exceptions from a successive Change of Substances.

IF either of the substances employed should change its properties, its attractions will, doubtless, be liable to alteration. This may be illustrated by many examples. It had been long known, that nitrous acid is capable of dislodging the marine from an alkaline basis ; but Margraaf was the first who observed that the latter expels the former. This phænomenon, unless we are acquainted with the nature of marine acid, eludes all explanation ; but now this is known, the problem is easily solved. The nitrous acid expels the marine, by means of a single elective attraction,

traction, (Scheme 42.), but phlogiston enters into the composition of the marine acid, and is attracted from it by other acids, especially by the nitrous, (XVII.), which, even though saturated with vegetable alkali, strongly attracts the inflammable principle; for nitre kept in a state of ignition for an hour or two, remains perfectly neutral, whence it is plain, that all the acid remains, but it is become so much weakened, by being phlogisticated, that it may be expelled by concentrated vinegar, (XXXVII.). Hence it follows, that part of the marine acid that is poured upon the nitre, yields its phlogiston, in consequence of the heat applied, to the nitrous acid, which in this state is expelled by that part of the marine which is not yet decomposed, (Scheme 55.). That this is the true explanation, appears from the nature of the thing, the necessary proportions, and the matter collected in the receiver, which is found

to consist of phlogistified nitrous acid and marine acid, both dephlogistified and in its ordinary state.

ON the same principle, white arsenic is capable, by distillation, of decomposing those neutral salts which contain the nitrous, but not those which contain the marine acid. White arsenic is nothing but a sort of sulphur, consisting of the arsenical acid, and a certain portion of phlogiston, (XX.). In this case, therefore, four substances come into action, (Scheme 56.); and as the nitrous acid strongly attracts phlogiston, and its connection with its basis is much weakened by the accession of that principle, the acid of arsenic is capable of expelling it: but the marine acid, already containing the inflammable principle, refuses to combine with a larger portion of it, it therefore remains unchanged, and the arsenical acid
has

has no power against the stronger, (Scheme 57.).

I HAVE long since observed, that the noble metals, though they resist the force of fire so obstinately, may be more or less calcined by solution in acids; and it will now be proper to add something concerning iron, which, above all, seems liable to this change, especially concerning its solution in the vitriolic acid. In the first place, we remark that a portion of phlogiston flies off during solution in the inflammable air; next, if the saturated solution, which is of a green colour, be filtered, and kept in a full and close phial, it will remain clear; whereas, if it be exposed to the air in an open vessel, it will gradually, but constantly, deposit ochre, a phenomenon which arises from two causes. For vital and respirable air attracts phlogiston so forcibly as insensibly to diminish that which is contained in the
solution

solution of iron. Such also is the nature of the vitriolic acid, that it will dissolve so much the less iron, the more destitute the metal is of phlogiston; whence it follows, that a quantity of acid sufficient for the solution of iron but little dephlogisticated, gradually becomes insufficient in proportion as the phlogiston is separated, and therefore earth of iron must fall to the bottom, which, however, again disappears on the addition of fresh acid. This decomposition is much accelerated by heat, and especially by boiling, and at last the green colour is changed to a dark red, and the whole solution assumes the nature of an ultimate ley, which is incapable of crystallization, as has been admirably shewn by Mr Monnet. Successive boiling, however, and cooling, bring about the dephlogistication sooner than continued boiling alone.

THIS ultimate lixivium, however, may be reduced by the addition of a little vegetable alkali, to white astringent crystals, like those of alum, whence some have been led to believe, that the transmutation of vitriol into alum is fully proved ; but this salt, when dissolved, may be totally changed into Prussian blue, by means of phlogisticated alkali, and, if common alkali be employed, affords nothing but ochre, and not a particle of alum, provided the vitriol be made by dissolving iron ; that indeed, which is extracted from pyrites, often contains alum, since clay frequently enters into the composition of pyrites.

WITH these truths in view, it is easy to answer, if any one should think of proving the reality of reciprocal decomposition by the case of alum, in which the acid seems to part with the earthy basis upon the addition of iron filings, and take
up

up the metallic, while, on the contrary, clay is dissolved in the last lixivium of vitriol, and precipitates the ochre. In the first case, we have iron combined with its proper portion of phlogiston, which, when it is put into a solution of alum, is taken up only by the excess of acid, which adheres more loosely than the saturating portion. And the abundant acid being taken away, the clay, being exactly saturated, falls down insoluble. These phenomena have therefore been hitherto ill understood, for at the precise point of saturation, clay is not precipitated by iron.

IN like manner, copper yields the acids to iron, while it attracts them from crocus martis. Hence the decomposition of vitriol of iron by copper, detected by Mr Margraaf, is easily explicable; it is by no means reciprocal, for copper precipitates iron only when it is dephlogisticated beyond a certain limit.

IN an open vessel, the inflammable principle is easily separated, especially by means of heat ; hence a solution of vitriol of iron must necessarily change in its nature almost every moment to a certain point, below which it is impossible to proceed in this way. It is the more surprising, that copper should be so easily dissolved in this experiment, since it is certain, that this metal is with great difficulty dissolved in vitriolic acid, unless it be in some measure calcined beforehand. But in the present instance, the earth of the iron attracts the phlogiston of the copper, which it soon loses again on the application of heat. The solubility of the calx, as well as the regulus, of copper, in a boiling solution of martial vitriol, is a clear proof of this conjecture. Concentrated vitriolic acid indeed attracts copper, when assisted by a sufficient heat ; but let it be remarked, that the vapours which then arise, are the phlogisticated

gified vitriolic acid, which shews, that a portion of the inflammable principle is carried off. Moreover, how the precipitations of metals from acids, by means of other metals, are to be properly understood, will be explained more at large hereafter.

VII.

Apparent Exceptions from Solubility:

It sometimes happens that no decomposition appears at first, though it really takes place. Fixed mineral alkali united with the acids to saturation, and dissolved in water, remains in the limpid solution on addition of pure vegetable alkali, nor is any conglomeration or precipitation to be observed. Hence chemists of great name have concluded, that the vegetable does not exceed the mineral alkali in attractive power ; but

let us suppose for a moment, that the mineral alkali is dislodged, should the solution become turbid? By no means, for the fossil alkali is soluble of itself, and cannot therefore impair transparency. From this phænomenon alone, therefore, nothing certain is deducible; but let the solution be evaporated, and there will be found at last uncombined mineral alkali, separately crystallized, and besides, vitriolated tartar, if Glauber's salt, cubic nitre, if quadrangular nitre, and digestive salt, if sea salt was subjected to the experiment, (Scheme 3.).

SOME metals precipitated from acids, by too much alkali, soon disappear again in consequence of solution. Platina and gold can scarce be precipitated in such a manner that the solutions will not remain tinged. Zinc, copper, nickle, and cobalt, afford no precipitate when an excess of volatile alkali is used, unless

unless they are contaminated by some heterogeneous substance.

THERE is yet another veil which often hides decompositions, as when the substance expelled from its combination is capable of dissolving the new compound, or at least does not hinder the water of solution from doing so. This happens not unfrequently when the acids of nitre and salt are expelled by those of greater power. Thus the vitriolic takes magnesia from the marine, but in such a way as totally to escape the notice of the senses; for the extricated acid, sharpening the water of the solution, immediately takes up the vitriolated magnesia, which is indeed otherwise of very easy solubility, and therefore no signs of it appear, until, by a spontaneous evaporation, the menstruum is so much diminished as to be incapable of dissolving the whole. Several instances of this kind occur in

the following paragraphs, and it is at the same time shewn how this impediment may be removed.

To this head we may also refer precipitations happening from a subtraction of the water of solution, upon the addition of a substance which, though it does not change the former combination, yet deprives it of its water, when there is not enough to dissolve both; whence the compound suddenly concretes into small crystals, nearly in the form of a precipitate. This happens when a proper quantity of concentrated vitriolic acid is poured into saturated solutions of vitriolated tartar, alum, corrosive sublimate, and other salts, not easily soluble in water, though their proximate principles cannot be parted by vitriolic acid. Vitriol of mercury is really decomposed by marine acid, which attracts the calx of the metal, and carries it down along with it to the
bottom

bottom for want of water: but concentrated vitriolic acid also, when poured into a solution of corrosive sublimate, throws down in its turn a white powder; whence some have immediately inferred that kind of decomposition which is generally called reciprocal; but the latter precipitate is found, on examination, to be nothing else than true corrosive sublimate deprived of the water of solution. Fixed vegetable alkali, particularly when dry and caustic, produces like effects in the same circumstances; I mean, when the basis attracts the acid with equal or greater force than the alkali employed.

THESE precipitations are seldom complete; for something generally remains dissolved in the liquor.

FINALLY, let me notice those anomalous phenomena which depend on apparent solubility. Liquor of flints, as
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is well known, contains filiceous earth, dissolved in water by means of fixed alkali. Upon dropping in an acid, the filiceous earth ought to be precipitated, as really happens, unless the liquor be diluted in twenty-four times its weight of water, or more; in this case, no cloudiness is perceptible, though even more acid be affused than is necessary for saturating the alkali. We have here an appearance of solution; but the truth is, that the filiceous particles are so dispersed in the abundance of water, that they cannot subside on account of the great proportion of their surface to their weight. As I have elsewhere explained this at greater length*, I need only give a short view of the matter here. I shall only add, that the earth cannot be dissolved by the neutral salt that is formed; for the filiceous particles fall down on ebullition, (which increases solubility upon other occasions),

* Op. vol. ii. p. 36.

sions), in consequence of the diminished density of the liquor by heat. Should any one object, that, for the same reason, other earths ought also to be suspended, he will readily find, on more mature consideration, that, 1. no other of the primitive earths is soluble in alkali, except the argillaceous, which is also soluble in acids, so that there can be no excess either of the one or the other without solution. 2. Calcareous earth is not precipitated from acid menstruums in a visible form by caustic fixed alkali well diluted, and gradually dropped in, till paper dyed with brazil wood is changed to a blue, provided the solution be first diluted with fifty times its bulk of distilled water.. The liquor remains clear for a time, but by degrees acquires a film on the surface. The solution employed ought to contain more calcareous earth than an equal quantity of the strongest lime-water, otherwise it might be said, that the calcareous

careous earth is really dissolved in the clear alkalised solution, and not suspended. If a single drop of aerated alkali be dropped into the clear solution without agitation, white clouds immediately come into view; but, if an equal drop be added, while the whole mass is shaken, no cloudiness ensues, for the motion prevents the coalescence of the separated molecules. Here then we have calcareous earth certainly suspended, and all ground of contradiction, I hope, removed.

VIII.

Exceptions from the Combination of three Substances.

THERE are some substances of such a nature, that three are capable of uniting without the exclusion of any one. The combination of two attracts a de-
termine

terminate quantity of a third, and sometimes of more, with so much force, that they become very closely connected, and are scarce to be separated by any art. This inconvenience more especially attends the dry way; for the earths mixed either with one another, or with salts, melt together without exclusion, which is also true of most of the metals. *A* is not indeed attracted by *a* and *b* with equal force, but rather *Aa* unites with *b*, or *Ab* with *a*, which yet is no reason why *a* should not exceed *b* in attraction, though the particular nature of the combinations prevents exclusion. Volatile alkali, marine acid, and the calx of quicksilver, volatile alkali, vitriolic acid, and magnesia; iron, vitriolic acid, and magnesia, not to mention other instances, adhere so closely in determinate proportions, that they cannot be separated by crystallization, and not easily in any other way.

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THIS also holds with respect to four ingredients, as borax with tartar, vitriolated magnesia with common salt, gypsum with common salt, and many others. To this head also belongs liver of sulphur formed in the dry way by vitriolated tartar and powder of charcoal, as in this case the phlogiston is first conceived to separate the acid, and generate sulphur, which then is dissolved in the alkali, and yields hepar; it may seem that the newly formed particles of sulphur can scarce persist in so great an heat, without either being sublimed or consumed, but the new compound is formed almost in the same moment.

FROM this property of certain substances, peculiar phænomena often arise. Should any one attempt to precipitate vitriolated magnesia, or muriated magnesia, by volatile alkali, he will indeed obtain some precipitate, but a new triple combination, a salt of a peculiar nature

nature, will be formed. If saturated solutions of nitrated lime and nitrated magnesia be mixed, an unexpected precipitate appears, consisting of a triple salt, compounded of both earths and the common acid, more difficult of solution than either of the ingredients, and on this account falling to the bottom. The new salt is taken up by a larger quantity of water. I must overpass many phænomena of this nature.

IX.

Exceptions from a determinate Excess of one or other of the Ingredients.

SOME chemists, I know, contend, that it is idle to suppose that a determinate excess of acid can be received by neutral or middle salts. Many instances, however, which I shall now mention, clearly prove the presence of such excess,

cess, which, agreeably to the nature of the thing, adheres more loosely than the saturating portion. Let perfectly neutral tartarized tartar be dissolved to saturation in distilled water; then let some genuine acid of tartar (XXIII.) be dropped in, and a white spongy substance will separate and fall to the bottom, which, when collected and examined, proves to be real tartar. What is the cause of this singular alteration? We shall easily ascertain it by considering the nature of the substances. Tartar is nothing but vegetable alkali with a greater portion of its own acid than is necessary to saturation. He who is acquainted with the taste of tartar, its effervescence with alkalis, the red colour it gives to blue vegetable juices, &c. can entertain no doubt concerning the excess of acid; nay, even till our own times, tartar was considered as an acid. Take away the abundant acid by the addition of vegetable alkali, and you will

will have tartarized tartar, which the French call vegetable salt, *sel vegetal*. Purified tartar is therefore nothing but tartarized tartar with a determinate excess of acid ; and when this is added to tartarized tartar, it is immediately generated, and, for want of a sufficient quantity of water to dissolve it, falls in great measure to the bottom. Tartar, therefore, and tartarized tartar, differ not in the nature, but the proportion of their ingredients ; nevertheless this cause produces a wonderful difference in taste and other properties, and especially in solubility. For tartarized tartar attracts water so forcibly, that it commonly deliquesces in moist air : on the other hand, one part of tartar requires 150 parts for its solution in a middle temperature ; which is so much the more surprising, as we are certain, that the superfluous acid, by itself, as well as tartarized vegetable alkali, readily unites with water. The excess, which occa-

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sions the difference, can neither be removed by crystallization, a moistened filter, or, in short, by any other way but saturation.

WE have therefore a manifest example, from which we may conclude, that vegetable alkali, though saturated, does not reject, but, on the contrary, easily admits an excess of the acid of tartar. There is here too a clear instance of attraction between a neutral salt and an acid of the same species as that which enters into the compound. If any other acid be poured into tartarized tartar, tartar is also separated; a phenomenon usually explained by saying, that the acid employed expels the tartar by superior attractive force. But tartar is not a pure acid, as was long supposed. Why then is the alkali united to it expelled at the same time? If the precipitation arise from superior attraction, why should acid of tartar effect it?

it? Why should vinegar, an acid really weaker, (XXXVII.)? That we may distinctly perceive what happens in this operation, let the tartarized tartar be imagined to be divided into two parts, so that one part *b* shall contain as much acid as is necessary for the other *a* to become tartar. Now let the foreign acid be added, so as to saturate the alkaline basis of the part *b*, the acid of tartar before combined with it will flow back to the portion *a*, which already tends to it with so much force, that it immediately seizes it, and is converted into tartar, provided any thing capable of weakening the cohesion of the principles in *b* but in a small degree be added.

SALT of Seignette shews the same phænomena. If a solution of volatile alkali be gradually saturated with acid of tartar, another species of soluble tartar will be formed, which is immediate-

ly clouded by excess of acid, and a new tartar is exhibited, very difficultly soluble, but, on account of the looser connection of the principles, more acid than the common sort.

BUT it is not only tartar which essentially requires an excess of acid. We have long been acquainted with several salts of this kind. Salt of sorrel consists of vegetable alkali and a peculiar acid in excess, (XXIV.). So also acid of arsenic, precisely saturated with vegetable alkali, cannot be crystallized; but if there be a proper excess of acid, we easily obtain beautiful crystals, (XX.). Hence it appears why it has hitherto been impossible to prepare Mr Macquer's arsenical salt in a crucible; for the necessary excess has always been expelled by the force of fire.

DUHAMEL and GROSSE have observed, that soluble tartar may be prepared

red from the absorbent earths, without however understanding the real nature of the operation. Now, as upon the addition of alkali, the excess of acid is saturated, and the whole mass becomes soluble, so chalk, by absorbing this excess, immediately generates a salt of difficult solubility, which of course is precipitated, (XXIII.); but when the excess of acid is separated from the tartar, nothing but tartarized tartar, which is very soluble, remains.

IN 1760, Mr Baumé published an experiment highly deserving of attention, from which he thinks it evident, that vitriolated tartar may be totally decomposed by nitrous acid in the humid way. By this instance, in the opinion of some modern writers, reciprocal affinities are proved beyond all doubt; but a closer examination will dissipate the whole ambiguity. It is therefore to be observed, *1st*, That vitriolated tar-

tar, dissolved in water, may be crystallized by evaporation, after the addition of a quantity of concentrated vitriolic acid, equal to one third of the salt. The crystals, with the accession of one third of their weight, remain dry, notwithstanding they are acid. More acid affords a deliquescent salt. The excess of acid cannot easily be driven off by distillation in a retort; this end may be more readily obtained by fusion in a crucible. Repeated crystallizations are of no avail. Washing with highly rectified spirit of wine is the best method of edulcoration. *2dly*, We know, that vitriolic acid in proper quantity completely decomposes nitre even in the moist way, whence its superior power of attraction is evident. There is here, therefore, no occasion for a distinction between the dry and the moist way. *3dly*, A third part only, or a very little more, of vitriolated tartar, dissolved in strong and hot nitrous acid, is decomposed, whatever quantity

quantity of the acid be employed.

4thly, There is no occaſion to apply heat, or uſe concentrated nitrous acid; for to a portion ſo much diluted that it emitted no fumes, I added a large quantity of powdered vitriolated tartar, ſet it in a cool place for thirty-fix hours, and then poured off the liquor; from which highly rectified ſpirit of wine precipitated a white powder, which being collected and dried, proved to be real nitre; and it deſerves to be remarked, that the vitriolated tartar which was not decompoſed, was ſo ſoluble by the aid of the ſuperfluous acid, as to be ſcarce ſeparable by ſpirit of wine.

5thly, Vitriolated tartar, with a proper exceſs of acid, as that in obſerv. 1. is not at all changed by the moſt concentrated nitrous acid. It is ſcarce ſufficient to moiſten the vitriolated tartar in powder with vitriolic acid; they muſt be diſſolved together in hot water.

6thly, Not only the nitrous, but the marine, the tartareous, and perhaps many

other acids, in like manner decompose vitriolated tartar. Glauber's salt, or vitriolated mineral alkali, is also totally soluble in marine acid; but about a third part only is decomposed, as Mr Kirwan has observed. 7^{thly}, Two thirds of the vitriolated tartar, which remain unchanged, form crystals with the excess of vitriolic acid, of the same nature with those which are procured in the way mentioned in the first of these considerations.

IF we weigh these observations, it will plainly appear that the same thing happens in the present case, as in that of tartarized tartar. Suppose *b* to be such a portion of the vitriolated tartar, as to contain exactly that excess, which the other portion *a* can receive. Nitrous acid of itself cannot deprive the vitriolic of its basis; but *a* attracting it at the same time, so far diminishes the resistance, that the nitrous is able
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to seize the alkaline basis of *b*, but its power is confined to certain limits. Suppose the vitriolated tartar to be divided into two parts, one of which affords its basis to the nitrous acid, and the other is not decomposed. We have here three powers: let that by which the part of the vitriolated tartar remaining entire attracts a determinate excess of acid, be called *A*; *B*, that by which the part to be decomposed endeavours to retain its basis; and, lastly, *C* the force of attraction of the nitrous acid to the same basis, it is obvious that no decomposition can be effected, if $A + C < B$, or if $A + C = B$; but if $A + C > B$, it immediately takes place.

WHAT has been said concerning the solution of vitriolated tartar in nitrous acid, is in like manner applicable to Glauber's salt, secret sal ammoniac, and perhaps many others, so that those decompositions cannot be deduced from
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the presence of phlogiston, in the alkaline salt. Concentrated solutions of nitre and digestive salt yield, upon the addition of acid of tartar, a real tartar, for the reasons above assigned; but quadrangular nitre and sea salt, of which the basis, mineral alkali, has a far different attraction for acid of tartar, afford no precipitation in experiments of this kind.

SEVERAL apparent exceptions originate from the removal or diminution of excess of acid; for various substances produce, with certain menstruums, salts so difficult of solution, that they cannot be held suspended without some excess. Thus lime is soluble in abundant acid of arsenic; but caustic volatile alkali, magnesia, lime itself, and, in short, whatever is capable of absorbing the abundant acid, immediately produces precipitation. If any one should hence conclude that lime is expelled

expelled by caustic volatile alkali and magnesia, he is certainly deceived, and ought likewise to maintain, that this is done by the lime itself. The precipitate, when examined, does not exhibit lime alone, but lime saturated with arsenical acid, which sufficiently explains the nature of the operation. The same phænomena occur with lime dissolved in phosphoric acid, and with many other substances of difficult solubility.

Almost all the metallic salts redden tincture of turnsole; and the excess can scarce be removed without destroying the salt.

BUT it is not the acids alone which sometimes exceed the limits of saturation; this is likewise true of the saline, earthy and metallic basis. Borax, however well purified, exhibits clear marks of abundant alkali, and still requires
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about an equal weight of sedative salt, to be completely saturated. Why the arsenical acid, though perfectly saturated with vegetable alkali, should yet expel the acid of nitre in distillation, I have already shewn, (VI.) ; but I may here add that the acid of arsenic likewise attracts an excess of alkali, when circumstances allow, and this force undoubtedly promotes the separation. On the same principles, the acid of arsenic, exactly saturated with vegetable alkali, decomposes liver of sulphur and soap, as Mr Scheele has discovered. In alum there is an excess of acid, so that it reddens turnsole, and is capable of receiving a still greater excess, and reciprocally of being combined with its own basis beyond the bounds of saturation. The calx of lead may also be combined in excess with plumbum corneum, and saccharum saturni. Turbith mineral and powder of algaroth have an excess of their basis, and, after
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the most careful washing, yield, on distillation, a portion of acid. I omit other instances; and from those which have been adduced, I think it evident that the doctrine concerning a determinate excess of one or other of the ingredients, is not only not absurd, but that it actually takes place on many occasions. The excess commonly adheres less firmly than the portion requisite for saturation, and therefore in many instances may be easily removed, but it is not on this account the less real. There is in these cases, as I have before remarked, an attraction between the saturated salt, and a determinate excess of the acid or the basis. Perhaps such an attraction takes place in all compound salts, and sometimes the power which attracts the acid, and at others, that which attracts the basis, may prevail, though we are as yet acquainted with only a few instances. It is also probable that the saline particles,

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when dissolved, can admit of a greater excess than when in a concrete state; at least, such is their relation to the matter of heat, a substance far more subtile, for when they coalesce after they have been separated, they part with a certain portion which they attract when dissolved. A new field opens here before us, as yet uncultivated, and indeed sufficiently difficult, since the attraction of compounds is weaker and sometimes scarce perceptible; sometimes, however, remarkable phænomena are to be derived from them alone. Let mercury, for instance, be digested in an equal weight of nitrous acid, with such a degree of heat as will prevent crystallization. At first the metal is taken up with effervescence in the common manner, but at length the generation of bubbles ceases, nor does any nitrous air arise, though in the mean time most of the mercury insensibly disappears. In
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this experiment, ordinary nitrated mercury, with a calcined basis, is formed, and this is afterwards saturated with mercury, that retains its phlogiston. If a solution of sea salt be added to a solution of this salt, a white powder is precipitated, which is real mercurius dulcis, and which in the last Swedish Pharmacopœia is directed to be prepared in this way*. When the mixture is made, the marine acid attracts the calcined mercury, and forms corrosive sublimate, which immediately seizing the complete mercury, becomes perfectly mild; nor does any thing else happen when calomel is prepared in the dry way.

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* Scheele in the Stockh. Transactions, 1778.

X.

How we are to determine the single Elective Attractions.

AFTER this view of the difficulties which may occur, let us hasten to our subject. Suppose $a, b, c, d, \&c.$ to be different substances, of which the attractive forces for A are to be ascertained.

A.] Let Ad , (i. e. A saturated with d ,) be dissolved in distilled water, and then add a small quantity of c , which may either be soluble in water by itself or not. First let it be soluble; then a concentrated solution ought to be employed, which, when dropped into a solution of Ad , sometimes immediately affords a precipitate, which, being collected and washed, either proves to be a new combination, Ac , with peculiar properties,

properties, or d is extruded, or sometimes both. It now remains to be examined, whether the whole of d can be dislodged by a sufficient quantity of c from its former union. It should be carefully noted in general, that there is occasion for twice, thrice, nay sometimes six times the quantity of the decomponent c , than is necessary for saturating A when uncombined. If c effect no separation, not even in several hours, let the liquor stand to crystallize, or at least become dry by a spontaneous evaporation; high degrees of heat must be avoided, lest they disturb the affinities, (IV.). Here the knowledge of the form, taste, solubility, tendency to effloresce, and other properties, even those which, in other respects, appear of no consequence, of the substances, is of great use in enabling us to judge safely and readily, whether any, and what decomposition has taken place. Sometimes the disengaged substance, whether

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that which was added or expelled, gives the operator much trouble, by concealing the genuine properties of the other, and therefore, if possible, should be removed, according to circumstances, either by water or spirit of wine.

NEXT, suppose c to be insoluble, as, for instance, a metal, let a bright and clean plate of it be put into the solution of Ad , and let it be observed, whether any thing is precipitated. By putting several laminæ in succession, we find at last whether a part only of d , or the whole, is separated. Sometimes no decomposition is effected, though the surface of the metal should have been lately filed, unless there be a small excess of acid; and as far as I have hitherto been able to collect, it is not always of consequence that the superfluous acid should be of the same nature as that which Ad contains or not.

IF only one of the compounds *Ad* and *Ac* be soluble in highly rectified spirit of wine, there is scarce any need of evaporation; for if the mixture be made, and left a few hours at rest, and then spirit of wine be added, that which cannot be dissolved in it is separated.

THE smell also often indicates what is taking place. Thus, vinegar, acid of ants, of salt, nitre, volatile alkali, are easily distinguished when set free. The taste likewise often informs an experienced tongue.

b.] Let *Ad* then be treated with *b* and *a*, &c. separately in the same manner.

c.] In like manner, let *Ac*, *Ab*, *Aa*, be examined in their order.

By such an examination properly conducted, the order of attractions is discovered. This task, however, exercises all the patience, and diligence, and accuracy, and knowledge, and experience of the chemist. Let us suppose only a series of five terms, a, b, c, d , and e , to be examined with respect to A , twenty different experiments are requisite, of which each involves several others: a series of ten terms requires ninety experiments, and, in general, if a be the number of the series, $n. \overline{n-1}$ will be the number of experiments.

d.] In like manner, each compound with a, c, b , should be examined in the dry way; but it must be in a crucible, or, if possible, in a retort heated to incandescence, that the volatile part may be collected at the same time.

SUCH, in general, is the method which I have followed; the continuance of
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this labour will perhaps discover various shorter paths, which will at least be convenient in certain cases. But we should be cautious in guarding against fallacies arising from the apparent exceptions above described.

XI.

The necessity for a new Table of Attractions.

THE tables which we have at present contain only a few substances, and each of these compared only with a few others. This is no reproach to the authors of them, for the task is laborious and long. Although, therefore, I have been employed upon it with all the diligence I could exert, and as much as my many other engagements would permit, yet I am very far from venturing to assert, that that which I offer is perfect, since I know with certainty, that

the slight sketch now proposed will require above 30,000 exact experiments, before it can be brought to any degree of perfection. But when I reflected on the shortness of life, and the instability of health, I resolved to publish my observations, however defective, lest they should perish with my papers, and I shall relate them as briefly as possible. In itself it is of small consequence by whom science is enriched; whether the truths belonging to it are discovered by me or by another. Meanwhile, if God shall grant me life, health, and the necessary leisure, I will persevere in the task which I have begun. I shall now explain the end I had in view, and my plan; should they be approved by the masters of the science, I hope that many will lend me their assistance, for it is easier to accomplish one or two columns, than to bring all to perfection: I exhibit a great number of the more simple substances which
occur

occur in chemistry. Many of these are not only compounded, but are easily resolved into their proximate principles, such as hepar, sulphur, the imperfect metals, &c. ; but they do not come into view here, but inasmuch as they effect composition and decomposition in their entire state ; but when their proximate constituent parts are separated, double attractions take place, which are not considered in this table.

MOREOVER, I have inserted many lately discovered, of uncertain origin and composition, such as the acids of fluor, arsenic, tartar, sugar, and sorrel ; of earths, magnesia and terra ponderosa ; of metals, platina, nickle, manganese, and siderite, of which more in the place belonging to each. In the obscurity of their origin, these substances agree with others that have been the longest known. Should they be derived from others, they ought not, on this account, to be

excluded, for they are now different, have constant properties, exercise their attractive powers without decomposition, and can at pleasure be obtained perfectly alike. It is therefore proper to inquire into their powers. Every substance that we employ is probably compounded, and although we are at present ignorant of its principles, they may hereafter be detected.

THE upper stratum of the table, if I may so call it, contains fifty-nine rectangles horizontally placed, which exhibit fifty-nine different substances, denoted by signs formerly in use, or by new ones, which I shall now therefore enumerate in the order of the adjacent numbers, for there is scarce any one in the following which does not appear in the first : 1. Is vitriolic acid ; 2. Phlogistified vitriolic acid ; 3. Nitrous acid ; 4. Phlogistified nitrous acid ; 5. Muriatic acid ; 6. Dephlogistified
muriatic

muriatic acid ; 7. Aqua regia ; 8. Fluor acid ; 9. Arsenical acid ; 10. Acid of borax ; 11. Acid of sugar ; 12. Acid of tartar ; 13. Acid of sorrel ; 14. Acid of lemon ; 15. Acid of benzoin ; 16. Acid of amber ; 17. Acid of sugar of milk ; 18. Distilled vinegar ; 19. Acid of milk ; 20. Acid of ants ; 21. Acid of fat ; 22. Acid of phosphorus ; 23. Acidum perlatum ; 24. Acid of Prussian blue ; 25. Aerial acid ; 26. Pure fixed vegetable alkali ; 27. Pure fixed mineral alkali ; 28. Pure volatile alkali ; 29. Pure ponderous earth ; 30. Pure lime ; 31. Pure magnesia ; 32. Pure clay ; 33. Pure siliceous earth ; 34. Water ; 35. Vital air ; 36. Phlogiston ; 37. Matter of heat ; 38. Sulphur ; 39. Saline liver of sulphur ; 40. Alcohol ; 41. Æther ; 42. Essential oil ; 43. Unctuous oil ; 44. Gold ; 45. Platina ; 46. Silver ; 47. Mercury ; 48. Lead ; 49. Copper ; 50. Iron ; 51. Tin ; 52. Bismuth ; 53. Nickle ; 54. Arsenic ; 55. Cobalt ; 56.

56. Zinc ; 57. Antimony ; 58. Manganese ; and, 59. Siderite.

THESE substances are, as it were, the heads of each column, at the top of which they respectively stand : to these those that are placed below bear this relation, that the nearer they stand, the stronger attraction they must be understood to have. Every column, therefore, not only must exhibit every one of the fifty-nine substances which is capable of being combined with the principal substance at the top, but also the order which such combinations follow. The double line distinguishes from the others the thirtieth stratum, which is the first that belongs to the dry way. The substances which occur in these rows refer also to the heads of the columns.

LASTLY, I have distinguished the horizontal rows, as well as the columns, by numbers on each side, that each
rectangle

rectangle might be more readily found and quoted. On account of the new substances, I am obliged to divide the table of single elective attractions into two parts; and when, from multiplied experiments, more than two can contain shall require admission, it may be conveniently divided into four parts; the first for the acids, the second for the alkalis and earths, the third for the inflammables, and the fourth for the metals.

XII.

Column First, the Vitriolic Acid.

CONCERNING the head of this column, as it is so well known, there is no occasion to premise much. So firm is its composition, that its proximate principles have not yet been discovered. Some late excellent experiments * have been

* Lavoisier's, in the Mem. of the Acad. of Paris, 1777.

been thought to disclose the structure of this acid; but they are, if I mistake not, to be understood in a different manner. Sulphur, when burned in a vessel filled with atmospheric air, and closed by means of mercury, absorbs a portion of vital air, and yields an acid of twice or thrice the weight of the burned sulphur. The acid, therefore, is supposed to have existed in sulphur, far lighter, and without air. The same thing is confirmed by the efflorescence of sulphureous pyrites, which is converted into vitriolated iron, not however without the absorption of a certain portion of vital air. To recover the air inherent in this acid, vitriolated mercury is reduced in a pneumatic apparatus by the aid of fire to its metallic form. During this operation, a large quantity of vital air, which is supposed to enter into the composition of the acid, is collected. Of these facts the following seems the true explanation. It has been fully
proved

proved by experiments, that every substance has a certain specific quantity of fire, which yet varies more or less in one and the same, according to the different states of solidity, liquidity, and fluidity, (XLVIII.). Now the vitriolic acid exists in a solid state in sulphur, but, on deflagration, deliquesces, and therefore recovers the heat proper to its liquid state. The specific heat of sulphur is to that of vitriolic acid as 0, 183 to 0, 758, that is, nearly as 1 : 4. But the acid extricated in this experiment contains very little water, only the quantity indispensably necessary to fluidity, which it attracts from the air and the mercury, that almost always contain it. But the less water the acid contains, the less is its specific heat, and it undoubtedly, in this case, is below 0, 758: let us suppose it to be 0, 549, and thus the proportion will be changed to 1 : 3. It follows, then, that the vital air enters into the composition of the
specific

specific fire. It is evident, that it loses its aerial form during the combination, which it cannot regain without a decomposition, since, in other experiments, it may be expelled from acids by alkalis and other saturating substances, in the same manner as the aerial acid out of chalk; but the heat only is set at liberty, and no part of the vital air. That which appears in the reduction of vitriolated mercury perhaps arises from decomposed heat, as we shall more clearly see in XLVIII. The principles of vitriolic acid have not yet therefore been satisfactorily set loose; for as to the matter of heat, it exists in every body yet known.

AMONG the substances hitherto tried; vitriolic acid adheres most tenaciously to

2.] *Caustic terra ponderosa*, which, when added to a solution of vitriolated tartar, generates

generates the ponderous spar, which remains insoluble at the bottom. The liquor contains caustic vegetable alkali, (Scheme 1.). Caustic or pure vegetable alkali is incapable of decomposing ponderous spar.

3.] Next stands *caustic vegetable alkali*, which, when added in sufficient quantity to a solution of Glauber's salt, yields vitriolated tartar and uncombined mineral alkali, which is unable to detach the vitriolic acid from vegetable alkali.

4.] Caustic *mineral alkali* precipitates the calcareous basis of gypsum, but the inverse experiment does not succeed.

5.] *Caustic calcareous earth* is superior to magnesia; for vitriolated magnesia (Epsom salt) is immediately decomposed in lime-water, and yields its acid to the lime. Moreover, lime separates volatile
alkali

alkali and all the metals from vitriolic acid.

6.] *Caustic magnesia* added to a solution of secret sal ammoniac, seems to produce no change which is sensible to the smell; but if the mixture be kept for a few days in a close phial, a distinct smell of volatile alkali will be perceived on opening it. The difference however of force is very small; so that the smallest diminution of that of the former, or increase of that of the latter, inverts the attractions. Hence a precipitation of vitriolated magnesia is often effected by caustic volatile alkali: for the alkali cannot easily be obtained quite pure, being either, on the one hand, contaminated by a small quantity of aerial acid, or, on the other, by quicklime, either of which effects a separation, the former by means of a double (V.), the latter by a single attraction. But the chief and perpetual cause

cause of precipitation, is the formation of a triple salt, more difficult of solution, as we have before explained, (VIII.).

7.] *Caustic volatile alkali* precipitates clay from vitriolic acid, and zinc likewise, unless it be added in sufficient quantity to redissolve the precipitate, (VII.). The same caution is applicable to the other metals; but there will be no ambiguity in the result, if the metal be insoluble in the precipitate. See also what is said of volatile alkali in XVI. and XXXIX.

8.] *Pure clay*, i. e. earth of alum, long digested in alkaline water, and then welledulcorated. I have already treated at sufficient length concerning the precipitation of alum by zinc, iron, and some other metals, (VI.). But the metallic calces seem to have the same degree of attraction for acids as clay, at least I have in vain tried to decompose

F vitrio-

vitriol of copper by clay ; and reciprocally calx of copper tinges a solution of alum, and a white sediment is deposited ; but this effect, as I have before explained, is owing to excess of acid.

9.—23.] This space perhaps belongs to the *metallic calces*. In all the tables of attractions which have been published, and even in that which I offered to the world in 1775, the metals were placed in the columns of the acids ; but upon farther reflection, I am forced to exclude them. That these substances are attracted and dissolved by acids, is known even to beginners ; but let it be remembered that they are not, as was supposed, taken up entire, and in their complete form by menstrua : for some particles of the acid carry off the superfluous phlogiston, while others dissolve the calcined metal. Since therefore they exist in the menstruum mutilated, and in a great measure deprived

prived of one of their principles, the condition under which the process may be referred to single attractions, does not exist. Hitherto the precipitations of metals by metals have been ill understood. When I observed many years ago, for the first time, that the series of the metals was the same with respect to all the acids, I was struck with great surprise at the coincidence, considering in how many particulars earths and alkalis differ with regard to them. I therefore began to entertain a suspicion, that the precipitation of metals depended, not on the election of the acids, but on some other principle, which I now certainly know to be the attractive power of the dissolved calces for the phlogiston of the precipitating metal. I have elsewhere treated of this subject *, and shall say more upon it in the sequel, (XLVII.). Complete metals therefore are properly excluded, but

F 2

are

* Diff. de phlogisti quantitate in div. metallis, § 2.

are the calces also to be set aside? They are really dissolved; and it seems agreeable to the nature of things to suppose, that the same acid would find some difference in sixteen different calces, in consequence of which it would prefer some to others. But as reasoning is fallacious, without the testimony of experience, I performed experiments with the calces, especially with those of silver and copper. I first procured as saturated a solution of silver in the nitrous acid as possible, which I could not indeed bring to such exactness that it would not redden turnsole; but the excess can scarce be taken away without the precipitation of the metallic salt. To this solution I added copper calcined by fire, and exposed it to a heat of digestion for several days; but though it was only very slowly dissolved, and the colour of the liquor changed to a blue, no signs of precipitation appeared. Another solution of
silver,

silver, equally saturated, dissolved that calx of mercury which is usually called precipitate *per se*, without any diminution of its transparency. I afterwards saturated nitrous acid with copper, and added the calx of silver precipitated by caustic fixed alkali; here there was only an inconsiderable solution, and no precipitation at all. It seems, therefore, that an acid takes up calcined metals without distinction, provided they have lost a certain quantity of phlogiston; for more or less of this principle makes a remarkable difference in some cases. Besides, when the nitrous acid is used, it sometimes happens that a calx, in a proper state, is gradually deprived of its phlogiston beyond the determinate limit, and then it is immediately rejected. Such events, proceeding from the peculiar nature of certain substances, must be carefully observed, lest erroneous conclusions should be drawn. I have before ob-

F 3

served,

served, that the calces attract each other, particularly those of zinc and copper *. These combinations, when dissolved in the same acid, produce, without doubt, triple salts, which deserve farther examination.

I have inserted the metallic calx in the order in which they are usually precipitated, since it may not be without use to be acquainted with it; but I have obliterated the horizontal lines, in order to shew that the acids have not yet been found to possess any power of selection.

24.] I here place *water*, since it dissolves most of the vitriols, and restores them unchanged. I am aware, indeed, that mercury, tin, bismuth, and antimony, are separated from the vitriolic acid, upon the addition of water; but it should be observed, at the same time, that

* *Ibid.* § 5. d.

that a large quantity is requisite, which first carries off the excess of acid especially necessary to these salts, and more slightly adhering to them, and then by the concurrence of heat seizes the remainder; but a proper quantity does not render the solutions turbid. We know that the vitriolic acid cannot be perfectly deprived of its superfluous water by boiling, but that it retains more than one-fifth of its weight; which therefore is the least possible quantity in metallic solutions. But by a sufficient quantity of water, and in a certain length of time, all the vitriols perhaps may be decomposed; in which case another place should be assigned to it, unless some other cause exerts its influence at the same time.

25.] *Phlogiston* comes last, to which, however, some of the moderns give the first place; but I am as yet unacquainted with any experiment from which

it can be safely concluded that phlogiston, in the humid way, and by attracting the acid, is capable of decomposing either neutral or middle salts, whether earthy or metallic. It is indeed strongly attracted by the vitriolic acid, as appears from the dark colour which it contracts from the smallest portion of oily matter, whether this be uncombined or intimately united with some other substance ; however, a sufficient quantity of water both prevents the offuscation, and removes it when it has been long present. Moreover, this acid, though in the most concentrated state, does not affect the phlogiston of charcoal, except by means of a proper degree of heat. Metals put into the vitriolic acid, lose a certain portion of phlogiston, but this is the effect of heat ; at least, of that degree which is excited by the solution ; and I have before observed that this privation is necessary

cessary to solution, (V.) and shall bring farther proof in XIII.

31.] In the dry way, *phlogiston* occupies the first place, for vitriolated tartar, Gläuber's salt, ponderous spar, and gypsum, lose their acid by the intervention of the inflammable principle of charcoal, and a sufficient heat.

32.] It is probable, that *terra ponderosa* decomposes vitriolated tartar in this way; it remains, however, to be confirmed by experiment.

33.] *Vegetable alkali* expels the volatile.

34.] So does *mineral alkali*; but whether the latter yields to the vegetable has not yet been examined.

35.] *Lime*, as well as

36.]

36.] *Caustic magnesia* deprives secretal ammoniac of its acid.

37.] All the *metals* probably, or rather their calces, expel the caustic volatile alkali. Experiments have been made with lead, tin, copper, iron, &c.

38.] *Volatile alkali*.

39.] *Pure clay* cannot detach the acids from ammoniacal salts.

XIII.

Column Second, the Phlogisticated Vitriolic Acid.

It was an emphatical and just observation of the ancients, that phlogiston lent wings to vitriolic acid, which, though it requires an intense heat to be sublimed before its union with phlogiston,

giston, afterwards evaporates spontaneously. The effects, however, vary wonderfully, according to the different proportions. For the acid, when fully saturated, constitutes common sulphur; if it be combined with a smaller quantity, it generates aeriform vitriolic acid, known likewise by the name of vitriolic acid air, which, when collected in mercury, cannot be condensed into a liquid by cold; is very light, not exceeding 000,246 in specific gravity. It immediately dissolves camphor, and extinguishes flame. An hundred grains of distilled water, scarce take up five of this aeriform acid; and I call this liquor, for the sake of distinction, *phlogisticated vitriolic acid*. This acid freezes in the same temperature as pure water; and what is remarkable, the acid elastic fluid remains in the ice, though in open vessels it forsakes the water. What is highly worthy of notice, is, that if it be exposed to heat in a tube hermetically

hermetically sealed for twenty days, a small quantity of sulphur is separated. Has the decomposition of heat any share in this phænomenon?

THE vitriolic acid, by the aid of fire, and properly treated, may be phlogistified by most substances containing the inflammable principle; but it cannot be reduced to this state by means of aerial acid. The phlogiston, in these operations, works wonderful changes, for a very fixed, heavy, inodorous, acrid liquor, becomes elastic, light, and so volatile, that its very penetrating smell threatens suffocation, and moreover so weak, that vegetable acid attracts alkali from it. I have not yet learned from experiment, whether there hence arises any variation in the elective attractions. I know that it dissolves alkalis; that caustic fixed alkali, and pure lime expel volatile alkali; and also, that lime-water precipitates magnesia;

magnesia ; and till the order of the other substances shall have been ascertained, I follow the same as in the preceding column. The neutral and middle earthy salts, formed by this acid, differ a little in figure, taste, and other properties, from those which contain pure vitriolic acid ; the difference, however, disappears in time, for the phlogiston gradually flies off.

BUT as all metals, in order to be soluble, must be deprived of a determinate portion of phlogiston, which, for each, is various, (for none can be taken up in its reguline state by vitriolic acid, without the separation either of inflammable air, or aeriform acid ; while, on the contrary, each, when deprived of a certain portion of phlogiston, is not only more easily dissolved without any farther loss of phlogiston, but likewise afford the same vitriols as in the preceding case ;) hence it necessarily follows, that the
phlogisticated

phlogifticated vitriolic acid fhould reject them ; and there are fome experiments from which it would appear that it really is fo. Zinc, which is quickly diffolved in diluted vitriolic acid, is changed, by the fame acid properly phlogifticated, into a white powder, which feems neither to be taken up by vitriolic nor marine acid. Each particle of the menftruum muft be loaded with phlogifton, otherwife thofe which are free from it act at firft in the ufual way ; but when they are faturated, folution ceafes. It is faid, that, by the aid of heat, the zinc is attacked, and that a quantity of inflammable air is extricated ; but I have not yet feen this. Flowers of zinc are taken up by the phlogifticated acid. Iron agrees with zinc, except that when it is too much calcined, it is fcarce foluble. Copper is not vifibly changed in this menftruum. Metallic precipitates procured by alkalis are by no means to be
confidered

considered as reguli minutely divided; for they are more or less deprived of phlogiston, as appears partly from what has been said above, and partly from the sediments thrown down by any metal used as a precipitant; which differ from the former both in splendour and nature; I have therefore no doubt but phlogisticated vitriolic acid will dissolve metals properly calcined; but I confess, that the particular phænomena have not been examined with proper attention. This volatile menstruum cannot be subjected to experiments in the dry way.

XIV.

Column Third, Nitrous Acid.

1.] This acid, likewise, seems to have such firmness of structure, that its principles have not hitherto been ascertained.

ed*. Exposed to the fire with various substances, it yields a great quantity of vital air; but it remains as yet doubtful whether the air existed uncombined in the acid, or is formed by its being sufficiently phlogisticated. This question will be discussed hereafter, (XLVI.). It exerts its elective attractions nearly in the same order as the vitriolic acid.

2.] *Caustic ponderous earth* cannot be separated from nitrous acid by the caustic vegetable alkali. When the aerial acid is present, it is precipitated in consequence of a double attraction; but if there be too much, it will be redissolved.

3.]

* The Count de Saluces politely sent me his letter on the generation of nitre, but he has not yet published his proportions, and I have not therefore had the satisfaction of observing this spectacle. Mr Thouvenel, too, has very lately obtained the prize from the Parisian Academy, for procuring nitrous acid from atmospheric air and putrid vapour.

3.] *Caustic vegetable alkali* decomposes quadrangular nitre, and forms prismatic.

4.] *Caustic mineral alkali*, precipitates nitrated lime.

5.] *Lime* precipitates nitrated magnesia.

6.] *Caustic magnesia* expels the volatile alkali from nitrum flammans.

7.] *Caustic volatile alkali* precipitates clay, zinc, and the rest of the metals.

8.] The place of *pure clay*, as also of the substances which follow has not been sufficiently determined.

9.—24.] The *metals* properly calcined.

25.] Water seems to prevent the accession of phlogiston. The acid just expelled from nitre, by vitriolic acid, contains about two-thirds of its weight of water.

26.] The nitrous acid soon detaches from the metals that portion of phlogiston which impedes solution; and when heat is employed, it sometimes goes beyond proper bounds, insomuch, that being too much calcined, they cannot be held in solution. Thus, tin and antimony are taken up with vehemence, but are soon let fall again to the bottom.

IN the dry way, the same order as in column first, as far as I have yet been able to learn, is observed. Phlogiston occupies the first rectangle, for in detonation the acid forsakes both ponderous earth and vegetable alkali to unite with phlogiston. Whether it be converted into vital air, I do not here enquire,

enquire, but the intensity of the deflagration, even in vacuo, clearly shews the presence of this air, which seems to be totally converted into heat; for nitre, in detonating with charcoal in close vessels, yields fixed and foul air, but scarce any thing fit for supporting ignition and respiration.

XV.

Column Fourth, the Phlogisticated Nitrous Acid.

NITROUS acid, especially when concentrated, eagerly attracts the inflammable principle, and, when contaminated with it, emits red vapours, and the liquor acquires a reddish colour, which, however, may be so far driven off by a slow distillation, that the liquor shall appear as limpid as the clearest water; such an acid is justly called *pure*. But

the colour which has been made to disappear, returns upon the smallest addition of phlogiston ; even the solar rays induce a yellow colour, and cause the acid to emit yellow fumes, as Mr Scheele has observed. Smoking nitrous acid, moreover, furnishes a fine proof, that different colours depend upon the different density of phlogiston ; for if nitrous acid, when red and concentrated, be diluted with about a fourth part of its bulk of water, it assumes a beautiful green colour, and yet emits red fumes ; but an equal, or a greater portion of water makes it blue, while twice or thrice its bulk destroys all colour. The red smoke which rises spontaneously, or may be driven off by heat, preserves its elasticity in a close vessel, and cannot be reduced to a liquid by cold ; it is therefore properly called *aeriform nitrous acid*. It is absorbed by water, which, with a certain portion, becomes blue ; with a larger, of a beautiful

tiful green ; when faturated, is yellow, and is then found to have received an increafe of one-third of its bulk. Such are the variations of *phlogifticated nitrous acid*. The blue fpontaneously emits *nitrous* air, the green fcarce any, and the yellow none at all. It well deferves to be noticed, that nitrous air fometimes exceeds the phlogifticated acid from which it has been expelled, tenfold in bulk, though water cannot receive above one-tenth*. Yellow nitrous acid, expofed to heat in a tube hermetically fealed, becomes of a more intenfè colour, the green or blue is turned yellow ; but by refrigeration the former hue is brought back. When the heat is continued for a long time, a colour permanent in the cold is acquired ; the tinging matter may be expelled in the form of a red vapour, and the acid will remain without colour ; but after refrigeration, the vapour again enters into the acid, un-

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less

* Prieftley,

less it be changed by a long continued heat *.

THE phlogisticated acid dissolves alkalis and metals, but it adheres to them very loosely, (XXXVII.). A sufficient quantity of acid, (unless it be quite saturated), in an open vessel, is not much prevented by the phlogiston from dissolving metals, for the particles which are contaminated, or which attract this volatile substance, fly off; and moreover, this menstruum attacks them on account of their inflammable part, and does not take up those which are calcined beyond certain limits. The calx of manganese, known also by the name of *magnesia nigra*, furnishes an admirable proof of the effects of a certain portion of phlogiston; for this calx contains a very small quantity of the inflammable principle, on which account a scarce sensible quantity is dissolved

* Priestley.

solved by pure nitrous acid, unless upon the addition of sugar, honey, or some other inflammable substance, capable of affording the necessary complement; but the phlogisticated acid perfectly dissolves it. These solutions precipitated by alkalis afford a white powder, readily soluble in acids, but which, by heat, is turned black, and recovers the properties of *magnesia nigra*; the white sediment, therefore, is nothing but the calx united with as much phlogiston as is necessary to its solution in pure acids; but the regulus contains a superfluous quantity, since red vapours are formed during its solution in nitrous acid. Mercury dissolved in nitrous acid, in the cold, deposits crystals spontaneously; by caustic volatile alkali, it is precipitated of a black colour, and differs in many other respects from that which, in consequence of the application of heat, has lost more of its phlogiston. The same remark is applicable

to iron, and some other metals. Every metal indeed must be deprived of a portion of phlogiston; but if this process is carried beyond certain limits, either no solution takes place, or one widely different from a real solution. The order of attractions, not having been sufficiently explored by experiment, is adjusted according to the preceding orders.

XVI.

Column Fifth, the Muriatic Acid.

1.] The acid of sea salt is nothing but water more or less combined with marine or muriatic air. This air is properly denominated *aeriform marine acid*, of which distilled water is capable of absorbing one half of its weight, and then yields *phlogisticated marine acid*. The acid recently expelled by vitriolic acid from sea salt, commonly contains three-fourths

fourths of water. This acid seems to exert its attraction in the same way as the preceding, though indeed in some cases more obscurely.

2.] *Ponderous earth*, dissolved in marine acid, cannot be expelled by pure vegetable alkali.

3.] *Pure vegetable alkali* expels the mineral. (See Scheme 3: and 32.).

4.] *Pure mineral alkali* expels lime, (Scheme 4.).

5.] *Pure lime* separates magnesia, volatile alkali, and the metals.

6.] *Pure magnesia* is to be placed before volatile alkali, for the reason before mentioned. The acid, magnesia, and volatile alkali, in a proper quantity, unite and form a triple salt: hence, in order to attain the proper proportion, a little
magnesia

magnesia is always separated on the addition even of the purest volatile alkali; but it is only the quantity necessary for attaining this end.

7.] *Pure volatile alkali* has no power against lime, (Scheme 5.); but the aerated precipitates it in consequence of a double elective attraction, (Scheme 36.). It precipitates metals.

8.] *Clay.*

9.—24. *Metallic calces.*

25.] *Water.* (See XII.).

26.] We shall see in the next paragraph, the relation of *phlogiston* to marine acid. Some of the substances adduced in the preceding columns are wanting in those which follow, for all cannot be dissolved in each menstruum; but I leave the rectangles which otherwise

wife would belong to them empty, that the difference may be the more striking.

IN the dry way, it may be presumed, that the same order is observed as in 1. and 3. till experiments shall have shewn the contrary. I confidently presume that the volatile metals, both with respect to one another, and those which are fixed, have by no means the same action as in the humid way. Corrosive sublimate is decomposed by all the acids, in consequence of a double elective attraction, as was above explained with respect to antimony; and this also is without doubt the case with lead, silver, and other metals saturated with acid of salt, which, when distilled with antimony, yield butter of antimony. If we are unacquainted with this cause, those experiments of Mr Pott, which shew that corrosive sublimate yields a butter with regulus of arsenic, and that,
on

on the other hand, not a grain is obtained with white arsenic, are absolutely unintelligible ; but, when we are acquainted with it, there remains no obscurity in these phænomena.

XVII.

Column Sixth, the Dephlogisticated Marine Acid.

THE illustrious Stahl reckons phlogiston among the proximate principles of the nitrous acid. All the experiments which have been since made, shew, that this acid attracts the inflammable principle with great avidity ; but we cannot hence draw any conclusion with respect to its composition, unless we are to believe an axiom in most instances false and contrary to phænomena, according to which, those substances which contain some common principles
of

of the same nature have a greater attraction than those which are formed of principles altogether different. Martial vitriol is not soluble in spirit of wine, though a dephlogisticated ley of it is very readily soluble, not to mention a great number of other instances. No one, at least on this ground, suspected the presence of phlogiston in marine acid, which so obstinately rejected that volatile principle ; but this is now certain, from the discovery of the ingenious Mr Scheele * : for *magnesia nigra*, which we have before considered as almost destitute of phlogiston, attracts it with so much force as to decompose the marine acid in a heat of digestion ; it is perfectly soluble in this acid, and is precipitated of a white colour from it, which shews the accession of phlogiston, (XV.). But the acid thus dephlogisticated, constitutes an elastic fluid, of a light red colour, of the same smell,

* Stockh. Transactions, 1774.

smell, if the greater mass be considered as hot aqua regia ; it is not easily soluble in water, and scarce leaves an acid taste, when made to pass through it ; but if it be confined over water for twelve hours, four-fifths are absorbed, and the residuum consists of common air : that which has passed through water is capable of making solutions, but the unwashed is the most efficacious. It should therefore be collected in cylindrical phials, successively adapted to the neck of the retort, which, when full, should be closed with glass stopples. A little water is beforehand put into the phials to absorb the muriatic air. Substances which are to be exposed to it should be put in with the stopples. It attacks phlogistic bodies with great vehemence ; whitens all the colours of vegetables ; reddens martial vitriol ; dissolves all the metals directly, and affords the same salts which are formed by the acid entire, which may
also

also be affirmed with respect to earths and alkalis; it changes white arsenic to a liquid acid, (XX.); always regaining its original form when its loss is restored; so that this truth is sufficiently proved both analytically and synthetically. It should be carefully noticed, that the red elastic fluid is properly entitled to the name of dephlogistated marine acid, and not the liquor in the receiver, which, although it has received a portion of the elastic fluid, yet consists chiefly of common marine acid, (XVIII.).

THAT the dephlogistated acid should form with alkalis, salts exactly like those which contain the entire acid, is a proof that they contain some of the inflammable principle by which the deficiency is supplied. What I have several times before observed, concerning the necessity of depriving metals of a certain portion of phlogiston, before

fore they can be dissolved in acids, is admirably confirmed by the power possessed by the dephlogisticated marine acid, of dissolving them all. This seems to take place according as the phlogiston adheres more loosely to them; but whether the order is the same as that of the preceding acids, must be decided by future experiments. Its volatility prevents its action in the dry way.

As marine acid is already sufficiently provided with phlogiston, it refuses a larger portion in its liquid state; but in its aerial form, having a larger surface, and being freed from its aqueous cover, it seems to admit more; nay, even to attract it with avidity, and when sufficiently supplied with it, to become inflammable. It may perhaps be suspected that dephlogisticated marine acid is nothing but the acid in an aerial form; on comparison, however,

I found a great difference, for the former is taken up by water slowly, not immediately ; it does not become inflammable by decomposing phosphorus gradually, but attacks it instantly, resolves it into white vapours, and regenerates aeriform marine acid ; it melts neither ice nor camphor, effects no change either on nitre or alum, &c. That which is at first collected, while a distinct odour of aqua regia is perceived, from a mixture of muriatic acid, with half the quantity of magnesia nigra, by a gentle ebullition, contains about nine-tenths of common air ; but that which is obtained towards the end, contains scarce one-eighth. The foul air which was mixed with the dephlogistified vapour, suffers a scarce sensible diminution from nitrous air.

XVIII.

Column Seventh, Aqua Regia.

WE have now no difficulty in explaining why a mixture of nitrous and marine acids should be capable of dissolving gold, though neither of them of itself attacks this metal. Gold must first be deprived of a portion of phlogiston, after which it is taken up by various menstrea. Now the nitrous acid, seizing phlogiston with great avidity, easily decomposes the marine, whether it be disengaged or united with any basis, as appears both from the smell of hot aqua regia, which is exactly like that of the dephlogistified marine acid, and likewise from the effect, for this menstruum, thus deprived of phlogiston, can repair its loss from any metal; in consequence of which, gold becomes soluble, particularly in the marine acid,

acid, (XVII.). Hence crystals of gold; procured by sea salt dissolved in nitrous acid, (for the two acids uncombined scarce afford any), and freed by edulcoration from the heterogeneous matters adhering to them, are found to contain the marine acid only. In this process, therefore, the nitrous acid has no other effect than to dephlogisticate the real solvent, as much as is necessary: that acid, however, alone, when concentrated by long continued boiling, directly attacks the inflammable principle of gold, very subtilely divided, such as occurs in the process of parting; it then dissolves the calx, and retains it so feebly, that it often falls down spontaneously, or in consequence of shaking. And this is the true explanation of Mr Brandt's experiment, who found that gold was soluble in nitrous acid*. There is no need to consider the other solutions by aqua

H 2

regia

* Acta Stockh. 1748.

regia one by one; we may only observe, that this compound menstruum does not always yield triple salts, for in those cases in which the nitrous or the muriatic acids can of themselves effect a solution, the compounds commonly crystallize separately, at least in part.

THE elective attractions here also follow the order set down in the preceding columns.

XIX.

Column Eighth, Fluor Acid.

How this acid may be expelled from fluor by the vitriolic, has now been known for a considerable time *. When disengaged, it always assumes and retains an aeriform state, till it comes in contact

* Stockh. Transf. 1771.

tact with water, which absorbs it as well as other aeriform acids ; and we thus procure *phlogisticated acid of fluor*, which gradually corrodes glafs, extracting particularly the filiceous part. This acid, however, in its aerial state, acts upon glafs much more efficaciously, especially if the vapours be hot, which, though they be loaded with filiceous earth, constitute a transparent elastic fluid. When it is dissolved in water, it deposits part of the filiceous earth under the form of a white powder, but the rest remains dissolved in the liquor. Let me enter into a short discussion, and enquire whether this be an acid different from every other, or mere muriatic acid, modified by an earthy basis. Peculiar properties distinguish it from every other acid, from the vitriolic and marine in particular, with respect to which doubts have arisen ; for when digested with a little calx of silver, and then depurated by gentle distilla-

H 3

tion,

tion, it does not form argentum corneum; nor with fixed alkali does it yield vitriolated tartar, or Glauber's salt, or digestive or sea salt; with lime it regenerates fluor; with magnesia it forms a crystallizable salt; with terra ponderosa, an efflorescing compound, and with clay, a sweet and viscid salt, like jelly: it also dissolves siliceous earth itself, which totally rejects all other acids, (XLIV.)

It is indeed true, that this acid is generally adulterated with a little of the marine, whence, without doubt, the resemblance of smell; but is the origin of the nitrous acid therefore to be deduced from the marine, because both are present in aqua regia? How small the portion of the acid of salt is, appears from the very sparing precipitation of silver and mercury from the nitrous acid. The fluor acid, as far as I have yet found from experiment,
neither

neither derives its origin from the marine nor the vitriolic; at least I cannot comprehend how the intimate union of an earthy basis should produce so wide a difference. We know that acids, in such a combination, become in some degree milder, and lose their acrimony. Why then should the fluor acid, when resolved into vapours, corrode, and sometimes perforate even glass, a property belonging to no other yet discovered, with whatever basis it may be united? If any one should attempt to prove, from nitrated silver, (*lapis infernalis*), corrosive sublimate, and other metallic salts, that the natural acrimony of acids is heightened by combination with certain bases, the opinion, if we examine into the matter closely, will appear to be groundless. It is clear, from an hundred instances, that the acrimony of acids is diminished in proportion to their saturation; to suppose it increased is repugnant to

the nature of the thing: besides, an extraordinary degree of vehemence is ascribed to these corrosive salts, because they attack animal bodies when they come in contact with them. But the true cause of the corrosion is the dephlogistication of the metallic bases, (XV. XVII.), which are for this reason capable of tearing away the inflammable principle contained in animal substances, for to this they always tend with great force; and thus they in some measure moderate their strong attraction, for the acids are insufficient to saturate them. The various hypotheses concerning the origin of the nitrous and marine acids from the vitriolic, are well known, but they remain to this day unsupported by any valid argument, as will also hereafter appear, if I mistake not, with respect to the fluor acid.

THE preceding acids attract alkalis in preference to earths ; but here a different order begins. Fluor acid, saturated with vegetable alkali, is decomposed by lime-water, and yields fluor and uncombined alkali. The acids which abound in phlogiston seem, for the most part, to prefer lime to alkalis. Ponderous earth, saturated with fluor acid, is soluble in a large quantity of hot water, and, upon the addition of lime-water, yields its solvent to the lime, an effect easily ascertained, for the liquor is rendered turbid, and fluorated lime is deposited. Fluor acid seems to take magnesia from vitriolic acid, but this does not hold with respect to lime ; hence, therefore, the first place might be assigned to magnesia ; but when I afterwards repeated the experiment, with all possible care, there was no appearance of precipitation. The sediment, therefore, in the first experiment, was perhaps siliceous earth, which

which quitted the acid when it came to be diluted in the solution.

IN the dry way, the order of this acid is made the same with the preceding, though it remains to be determined by experiment. It is certain, however, that fluor mineral is not decomposed by caustic fixed alkali, (Scheme 51.), though aerated alkali effects a decomposition; but it is in consequence of a double elective attraction, (Scheme 63.).

XX.

Column Ninth, the Arsenical Acid.

That admirable discovery, which disclosed the composition of marine acid, at the same time points out a method of acquiring pure acid of arsenic. Macquer's arsenical salts indeed shew evidently the acid nature of white arsenic;

senic: the pure acid, however, could not be separated before the method of dephlogisticating the muriatic acid was brought to light. We are now acquainted with two ways. In the first, one part of pulverized black magnesia, and three parts of acid of salt, of which the specific gravity to that of water, should be as 5 : 4, are mixed in a tubulated glass retort, having a bulb capable of containing four times the quantity of the ingredients: to the retort a receiver is adapted, containing one-fourth of pulverized white arsenic, together with one-eighth of distilled water: the retort is to be heated in a sand bath, and the manganese will quickly dephlogisticate the marine acid, which again regains its complement from the white arsenic. The acid of salt being thus regenerated, unites with a portion of the water, and dissolves part of the arsenic: the rest of the water is seized by the arsenical acid, as it
is

is gradually dephlogisticated; so that the liquor of the receiver is divided into two strata, and in a few hours all the arsenic disappears: at this period the liquors should be distilled to dryness in a retort. That which is collected in the receiver, consists of butter of arsenic, and marine acid unmixed; but the white residuum in the retort, which should be heated red hot to free it completely from acid of salt, exhibits real acid of arsenic in a solid form, (Scheme 17.), which is easily soluble in water.

THE other method, is as follows: let two parts of pulverized white arsenic be dissolved in a tubulated glass retort, in seven parts of marine acid, by slow boiling. Let the liquor collected in a receiver luted to the retort, be poured back, and at the same time three and one-half parts of nitrous acid, of the same specific gravity as the above-mentioned marine, be added; then let a
receiver

receiver be adapted again, but without a lute. By the assistance of the heat, the nitrous acid seizes the phlogiston of the arsenic, and emits red fumes ; but the distillation must be carried on till no more of these fumes are seen. Then, one part of white arsenic is to be added, which should be in like manner dissolved by gentle boiling, and afterwards one and one-half part of nitrous acid, which dephlogisticates the dissolved arsenic with effervescence, and red fumes arise. Lastly, distil to dryness, and the residuum, after slight ignition, will be found to consist of pure arsenical acid, which is fixed in the fire, attracts moisture in the open air, and is soluble, if it be sufficiently dephlogisticated, in twice its weight of water. It should be freed by thorough washing in a filter from the siliceous powder, which comes from the corrosion of the glass during ignition.

ARSENICATED

ARSENICATED vegetable alkali is immediately decomposed by lime-water, and the alkali is disengaged. I have scarce any doubt but ponderous earth and magnesia prevail over alkaline salts; though I must confess that this conjecture has not been yet confirmed by experiment.

IF acid of arsenic does not dissolve metals in their complete state, it at least dissolves them when calcined to a due degree. It is, moreover, to be observed, that no inflammable air is generated during the solution of iron; for the phlogiston, being absorbed by the acid itself, regenerates white arsenic.

XXI.

Column Tenth, Acid of Borax.

THE substance commonly called sedative salt, is more nearly allied to acids than any other class of bodies. It reddens turnsole; saturates alkalis and soluble earths. It also dissolves various metals, and has other properties which shew its acid nature; and it seems better entitled to the name of acid of borax, than that of sedative salt.

DEPURATED borax may be decomposed by boiling with lime; the acid forsakes the caustic fossil alkali to seize the lime, and produces a salt scarce soluble. That the same thing takes place with vegetable alkali, saturated with acid of borax, is hitherto only a probable conjecture; as also on the addition

tion of ponderous earth and magnesia.

Acid of borax attacks metals with difficulty. The easiest way to combine these substances is by a double affinity; but, to avoid mistakes, the borax should be saturated with sedative salt, of which there is required somewhat above an equal weight, before the reaction of the alkali entirely ceases. I have dropped a solution of such borax into metallic solutions, freed as much as possible from superfluous acid. Gold, platina, bismuth, and manganese, dissolved in their proper menstrua, remained undisturbed; but solutions of mercury, lead, copper, iron, tin, nickel, cobalt, and zinc, were immediately rendered turbid, and yielded metallic salts of very difficult solubility, (Scheme 28.).

XXII.

Column Eleventh, Acid of Sugar.

MOST vegetables shew manifest signs of acidity in their fruit or juices ; and as the very few vegetable acids, which are known with tolerable accuracy, have different properties, the diligence of posterity will certainly bring to light a great number. The chief obstacle which prevents us from becoming acquainted with them, is the great difficulty of purifying them ; for they are so involved in other substances, as scarce to admit of being extricated. I produce but a few here, of which the greater part labour under the imperfection of being destructible by fire. Do all of them agree in their primary principles ? Can they be transmuted ? These questions must be determined by

accurate experiments, made with this view. Of the acids of tartar, lemon, and milk, it is certain, that they all, upon the addition of spirit of wine and water, and after a digestion of several weeks, are changed into vinegar. At present they must be considered as different, since they can always be obtained perfectly the same, and possess properties perfectly distinct, constant, and of the utmost importance in chemistry.

THE acid which exists in sugar, is found to be so closely united with an oily matter, that it has never yet been possible to separate it, but by the nitrous acid which destroys that matter. For this purpose, let six—eight parts of strong nitrous acid be poured upon one of white sugar, reduced to powder, in a glass retort, and be gently boiled. The nitrous acid in a short time seizes the phlogiston, and emits red fumes; after the cessation of which, the liquor
remaining

remaining in the retort should be poured into a large vessel, and it will afford crystals of a prismatic form, and very acid taste. If the lixivium be dephlogisticated by two—four parts of nitrous acid, it will again deposit crystals of inferior purity indeed, but they may be purified by solution and repeated crystallization. This acid may be also obtained from honey, gum arabic, and spirit of wine, by means of the nitrous acid, but in smaller quantity. It possesses all the properties of acids in general; and besides these, several peculiar to itself, by which it is distinguished from all others. It totally differs from nitrous acid, and in many respects is of an opposite nature; so that its origin cannot with any degree of probability be ascribed to that acid. But this question is considered at greater length elsewhere *; the attractions

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are

* Opusc. vol. i. p. 251.

are the chief object of the present dissertation.

It attracts lime most strongly, and forms with it a saline combination, insoluble in water, whence we may easily perceive the necessity of lime-water in the refining of sugar. The juice of the sugar-cane has an excess of acid, which prevents the concretion of the sugar. For if this acid be added to a solution of perfect sugar, it will not yield crystalline grains, but a glutinous mass. Nothing can therefore be of greater service than lime-water, which not only absorbs the uncombined acid, but likewise forms an insoluble salt, that either falls to the bottom or floats in the froth. Alkalis indeed saturate this acid, but they form salts which can scarce be separated on account of their solubility.

PONDEROUS

PONDEROUS earth, magnesia, and alkalis, yield this acid to lime. It attacks almost all the metals. Its comparative power, with respect to other acids, will soon be seen in the columns of alkalis, earths, and metals. This acid is an excellent test for detecting lime any way dissolved or suspended in water, for the smallest drop of a solution of it immediately seizes the lime, forming with it a white insoluble powder, which falls to the bottom. If we know the quantity of lime in a given weight of this saline powder, we easily learn, at the same time, the quantity of lime, in any case, from the sediment, completely precipitated from a determinate quantity by means of this acid, carefully collected, washed, and weighed.

It cannot sustain experiments in the dry way. The crystals alone, being exposed to fire in a glass retort, partly

indeed sublime, almost unaltered, but the greater part is resolved into an acid liquor, which will not crystallize, as also happens to the sublimate, if it be again subjected to the operation. During this destruction of the acid, a great quantity of inflammable air and aerial acid is extricated. The acid of sugar undoubtedly abounds with unctuous matter, yet it is of a very subtile nature, for in the fire it leaves no traces of charcoal or soot.

XXIII.

Column Twelfth, Acid of Tartar.

I HAVE above explained the nature of tartar, (IX.), and shall now briefly mention the process for obtaining the acid pure. To an hundred parts of cream of tartar, dissolved in boiling water in a tin boiler, let small quantities
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of chalk, washed, dried, and pounded, be added at intervals. This must be continued as long as any effervescence is excited by the addition; about twenty-eight parts will be required. When the point of saturation has thus been attained, let the liquor be decanted and evaporated to dryness; it will yield fifty parts of tartarized vegetable alkali. The powder remaining in the bottom is lime saturated with the abundant acid of tartar, which, when washed and dried, amounts to above triple the chalk used, *viz.* an hundred and three. Let this compound be put into a phial, and let there be gradually added three hundred parts of vitriolic acid, containing two hundred and seventy of water, and thirty of the strongest acid. Let the mixture be digested for twelve hours, and often stirred with a wooden spatula. Lastly, let the clear liquor be poured off, and the residuum washed till it has lost its acid taste; let the wa-

ter be filtered and added to the decanted liquor. We have here a solution of acid of tartar, which, if evaporated to dryness, affords near thirty-four parts of a crystalline mass. To try whether it contains any vitriolic acid, let one or two drops of a solution of sugar of lead be dropped into the diluted solution, a white sediment will immediately fall down, upon which concentrated vinegar should be poured, and it will soon disappear, if it consist of lead, saturated with acid of tartar; but vitriol of lead will not be dissolved. Should some of this be detected, it shews that the acid of tartar is adulterated; but it may be easily purified by digestion with a small quantity of tartarized lime. On the other hand, if too little vitriolic acid has been added, some acid of tartar will remain in the residuum, which is easily tried by throwing it on red hot coals; for pure gypsum neither grows black in the fire, nor emits an odour of spirit
of

of tartar, which, however, happens, if it be contaminated with tartarized lime. A filtered solution of acid of tartar evaporated to dryness will gradually deposit crystals in a cool place, which generally consist of divaricating lamellæ.

IF newly burned lime be used in the place of chalk, twice the weight of tartar will be totally decomposed, and therefore there will be uncombined vegetable alkali in the liquor; but aerated lime can only absorb the excess of acid, and the tartarized tartar will remain unaltered. An hundred pounds of purified tartar contains about twenty-three pounds of pure vegetable alkali, forty-three of saturating, and thirty-four of abundant acid. The difference of wines, and of processes for purification, will doubtless occasion some difference,

rence, but I have not yet been able to ascertain the limits.

FROM what has been said, it appears that lime, with respect to acid of tartar, has the superiority over vegetable alkali, which is also true of ponderous earth and magnesia ; for these earths, when deprived of aerial acid, and added to an exactly neutral solution of tartarized vegetable alkali, in a few minutes attract the acid of tartar in a heat of digestion ; and evident signs of uncombined alkali appear on adding the proper tests. Mineral and volatile alkali exhibit the same phænomena. To ascertain whether lime or ponderous earth prevails, I dropped lime-water into a solution of tartarized ponderous earth, by which it was quickly rendered turbid, so that every doubt with respect to the superior attraction of lime is removed.

CRYSTALLIZED

CRYSTALLIZED acid of tartar, when exposed to fire, immediately grows black, and yields a spongy charcoal, which, however, soon turns white, if heated to incandescence, and is much contracted in bulk. When distilled from a glass retort, it affords, in the receiver, a phlegm scarce acid, together with oil; the carbonaceous residuum consists of a portion of earth, which shews no signs either of alkali or acid. Hence, therefore, it appears, that there exists oil in this acid, which is destroyed in the fire, and is by no means convertible into fixed alkali. Treated with nitrous acid in the method above described, (XXII.), it afforded no acid of sugar, and could not indeed be so much deprived of oily matter, as not to grow black in the fire. Some person is said, however, to have succeeded in converting acid of tartar into acid of sugar, which I have not yet been able to confirm by a repetition of the experiment.

riment. Acid of tamarinds, and perhaps of berberries, seem to agree in all respects with that under consideration.

XXIV.

Column Thirteenth, Acid of Sorrel.

SALT of sorrel is vegetable alkali saturated in excess with a peculiar acid, and therefore of the same nature as tartar. To obtain this acid pure, is a work of difficulty. The vitriolic, nitrous, and muriatic acids, attract indeed the basis, but it is very hard to free the acid, thus set loose, from all impurities. An hundred and thirty-seven parts of chalk perfectly decompose an hundred of this salt, attracting both the saturating and excessive acid. The clear liquor yields thirty-two parts of aerated vegetable alkali; nearly the same quantity

tity as is obtained by fire. The sediment contains *forrelled* or *oxalited* lime, which, after edulcoration and exsiccation, weighs an hundred and seventy-three. The component parts of this salt cannot be separated like those of tartar, for the acid of sorrel takes lime from the vitriolic. Mr Scheele discovered another process. He added the abundant acid of salt of sorrel, saturated with volatile alkali, to a nitrous solution of terra ponderosa; an exchange of principles immediately took place, in consequence of a double elective attraction; and the ponderous earth, with the acid of sorrel, a compound difficult of solution, fell to the bottom, (Scheme 25.). This sediment is decomposed by acid of vitriol, which prefers ponderous earth to every substance yet known; and the acid desired may be poured off; but as it has been but lately disengaged, its properties have been little examined. Meanwhile, it
seems

seems more nearly allied to acid of sugar than of tartar ; it differs, however, from both, for the abundant acid of sorrel forms, with vegetable alkali, salt of sorrel, analogous to tartar, but decrepitating in the fire, fusible, scarce turning black, and capable of being totally decomposed by aerated lime,—properties not belonging to tartar. Now, saccharated vegetable alkali agrees neither with tartar nor salt of sorrel.

I KNOW with certainty that acid of sorrel prefers lime and ponderous earth to alkaline salts ; but it is as yet doubtful whether this be true of magnesia.

THIS acid is also destructible by fire, but it neither swells so much, nor turns so black as acid of tartar ; by distillation, a phlegm, far more acid than that which is separated from tartar by this process, but no oily matter, is obtained. Genuine salt of sorrel, as it is found in the shops, varies not a little in the proportion

portion of its proximate principles. An hundred parts of some specimens yield, on combustion and elixation, but thirty-one of vegetable alkali, while, to saturate the excess of acid, there is required an hundred and twelve and one-half. Others afford above thirty-seven, and require not above eighty-seven for saturation. It is obvious, that in the former case the saturated acid is to the abundant as $1 : 3\frac{1}{2}$, but in the latter as $1 : 2\frac{1}{2}$. The abundant portion is always larger than the saturated, which explains the stronger acidity of this salt compared with tartar. But the difference perhaps depends solely on the place where the forrel grows, or on the method by which the salt is extracted. The acid of forrel, (or more properly, perhaps, the *oxaline* acid), when procured by distillation, precipitates silver, quicksilver, and lead, from the nitrous acid; with alkalis, forms crystallizable compounds, and, by evaporation without

out addition, may be reduced to acid crystals.

XXV.

Column Fourteenth, Acid of Lemon.

ALTHOUGH the acid of lemon has been long known, it has been but superficially examined. The expressed juice is to be freed from mucilage and fœculent matter, by a long subsidence, and should then be exposed to cold, that the watery part may be frozen. It seems to contain a little vegetable alkali, for upon dropping in acid of tartar, in a few days a small quantity of tartar is found at the bottom. Stahl affirms that acid of lemon, saturated with crabs-eyes, and with the addition of a little spirit of wine, insensibly assumes, if it be kept in a phial slightly stopped, the nature of vinegar. An
equal

equal quantity of the same juice of lemon requires, for its saturation, of pure vegetable alkali sixty-nine parts, of pure mineral fifty-one, and of volatile twenty-five. These compounds do not easily crystallize.

It remains to be determined, by a greater number of experiments, whether acid of lemon certainly prefers lime, ponderous earth, and magnesia, to alkalis.

THE acids of fluor, arsenic, borax, sugar, tartar, sorrel, and phosphorus, agree in this respect, that if they be saturated with earths they are scarce soluble in water; and, therefore, if small quantities of earth be added, the solutions remain clear, on account of the excess of acid, but near the term of saturation they become a little turbid; and when this is attained, all that was dissolved is instantly precipitated, and can scarce

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be again dissolved but by excess of acid. The same thing is perhaps true of some other acids, but not of all.

XXVI.

Column Fifteenth, Acid of Benzoin.

THE resin, which, in the shops, passes by the name of *benzoin*, or *assa dulcis*, contains an acid salt, which may be separated by sublimation, and concretes into crystalline filaments or spiculæ. It may be acquired in the humid way more free from oily matter, by extracting the acid with lime, and then separating the compound with muriatic acid *. The acid of benzoin being dislodged, falls to the bottom, uncombined, and more difficult of solution than when united with the lime.

BOILING

* Scheele in the Stockholm Transactions, 1775.

BoILING water takes up one twenty-fourth of its weight ; but at the ordinary temperature scarce more than one five-hundredth. The taste, approaching to that of sugar, gives a slight sensation of acrimony, but none of acidity. It, however, reddens tincture of turnsole.

SPIRIT of wine readily dissolves it, even without heat.

It is totally resolved by fire into white vapours : it is, however, fusible with smoke, on the sudden application of a sufficient heat ; but can scarce be inflamed without the actual contact of some burning substance.

It readily combines with alkaline salts ; but none of the compounds, except that with mineral alkali, afford crystals, that are not liable to deliquescence.

LIME-WATER, dropped into the solutions, precipitates the alkaline bases, as also magnesia and clay. Lime, therefore, exceeds them in attractive power, but it is unable to separate ponderous earth; nor does the latter, when burned and dissolved in water, precipitate lime united with acid of benzoïn; so that here a combination of three ingredients seems to take place.

THE earthy salts, containing acid of benzoïn, are with difficulty dissolved in water, especially those that contain the ponderous and calcareous earths.

XXVII.

Column Sixteenth, Acid of Amber.

A CRYSTALLIZED volatile acid may be obtained from amber, by distillation, together with an acetous liquor and an oil.

oil. The acid may be in some measure purified by solution, and a second crystallization. That which I used in the following experiment was thus prepared; it shews evident signs of acidity.

COMBINATIONS of this acid with alkalis may indeed be made to crystallize, but they are all deliquescent, except that into which the mineral alkali enters. Lime and ponderous earth afford salts of difficult solubility; clay yields crystals, and magnesia a compound like gum.

THE metals, when duly dephlogistified, are soluble in this acid, and for the most part they afford permanent crystals.

PONDEROUS and calcareous earths, and magnesia, take this acid from alkalis. Ponderous earth also precipi-

tates fuccinated lime and magnesia ; lime-water makes no change in the solution of fuccinated ponderous earth, but it distinctly prevails over magnesia.

XXVIII.

Column Seventeenth, Acid of Sugar of Milk.

BARTHOLET first mentioned sugar of milk in the year 1619 *, but no one till Mr Scheele gave a complete analysis of it †. An hundred parts of this salt yield fifteen and one half parts of acid of sugar, and of another acid hitherto found only in sugar of milk, and which is here to be considered about twenty three and one half.

THIS

* Encyclop. Hermetico-dogmatica.

† Stockh. Transf. 1780.

THIS acid is obtained in the form of a white powder, and is not easily soluble in water, for sixty parts of boiling water take up but one of the acid. The solution turns turnsole red.

IN combination with alkaline salts it forms compounds far more soluble indeed, but still requiring a weight of boiling water many times exceeding the solvend. The compounds formed by this acid and earths, are scarce soluble at all. As to attractions, alkalis observe the usual order. Ponderous and calcareous earths, and magnesia, are superior to alkalis, but it is difficult to determine the superiority among them, as they are scarce soluble.

XXIX.

Column Eighteenth, Distilled Vinegar.

THIS acid, produced, during fermentation, from the preceding, which may in some measure be denominated crude, differs from them in the great inferiority of its attractive power for earths and metals ; but, on the other hand, exceeds them in subtilty, not being altered by distillation. Vinegar also contains phlogiston, but more intimately combined, or at least more concealed. It has been mentioned above that acid of tartar, digested with water and spirit of wine, affords vinegar. B. de Vigenere long ago observed, that crystals of tartar sometimes form in vinegar*. An acid also, very nearly resembling vinegar, may be procured by distillation from guaiacum
and

* Du feu & du sel, cap. 35. 1608.

and birch, from wax, fugar and amber, which is not to be confounded with acid of fugar, and falt of amber.

PURE lime cannot detach vinegar from fixed alkali, and it therefore seems to resemble the vitriolic, nitrous and muriatic acids in its attractions; and I have disposed them in the same order, though the priority of ponderous earth has not yet been confirmed by experiments.

I CONJECTURE, that, in the dry way, the same series, as in the fifth column, prevails, till I have leisure to confirm or correct this opinion by experiment.

XXX.

XXX.

Column Nineteenth, Acid of Milk.

To obtain the acid of milk, curdled by spontaneous acescency, let the whey be collected and evaporated to one-eighth. This residuum is to be saturated with lime, that the phosphorated lime may be separated; then let the calcareous earth that has been dissolved be precipitated by acid of sugar; and at last by highly rectified spirit of wine, the acid of milk is obtained free from the phosphorated lime, sugar of milk, vegetable alkali, and mucilage which milk contains*.

THIS acid seems to be intermediate between vinegar and acid of ants; it, however, exceeds vinegar in attractive power. By the addition of spirit of
wine,

* Scheele, Act. Stockh. 1782.

wine, it is really changed into vinegar, after a month's digestion.

WITH the alkalis, it forms deliquescent salts, and also with the earths, among which magnesia, contrary to what would be expected, forms the most permanent combination. Scarce any metal, besides zinc, forms crystals with this acid; not even lead, which yields a sweet solution, and deposits some vitriolated lead.

WITH respect to alkalis and earths, the order of attractions is the same as that of vinegar.

XXXI.

Column Twentieth, Acid of Ants.

THIS acid approaches very near vinegar; they differ, however, in many respects.

respects. The former forms with magnesia, zinc, and iron, crystallizable salts; the latter only deliquescent. Its combination with magnesia is peculiarly remarkable*.

ITS attractions have hitherto been very imperfectly examined; in the mean time, as far as has hitherto appeared, this acid observes the same order as vinegar; which, however, is weaker, as the following columns shew.

ALL the acids of vegetables, as well as that of ants, may be totally resolved into an elastic fluid, consisting partly of aerial acid, and partly of inflammable air.

XXXII.

* Opusc. vol. ii. p. 389.

XXXII.

Column Twenty-first; Acid of Fat.

THE celebrated Crell, by repeated distillations of fat, obtained from 2 lib, $14\frac{1}{8}$ ounces of oil, of charcoal $10\frac{1}{2}\frac{2}{4}$, and of acid $7\frac{1}{4}$ *.

THE salts formed by this acid, saturated with alkalis and earths, are very like those that vinegar generates with the same bases. Alkalis yield it to earths. A comparison of this with other acids will be found in the sequel.

XXXIII.

* Chemische Journal.

XXXIII.

Column Twenty-second, Phosphoric Acid.

ANOTHER acid which pervades all the kingdoms of nature, is especially obtained from human urine, by collecting the substance, usually called microcosmic salt, and fusing it in the fire : but it is to be observed, that this is a triple salt, and always contains two acids, the phosphoric and *perlaticum*, which shall be immediately more fully described, together with volatile alkali. When the acid is obtained in water by slowly burning phosphorus in the air, it abounds with phlogiston ; which however, in an open vessel, is gradually dissipated : it thus becomes much fitter for ascertaining attractions than the former ; for the presence of perlatic acid in that, may give rise to a diversity in the decompositions.

THE acid of phosphorus prefers lime to alkalis ; and therefore alkalis united with it, are immediately rendered turbid by lime-water, and a saline powder, very difficultly soluble in water, is gradually deposited, consisting of lime saturated with phosphoric acid. As phosphorated vegetable alkali can receive an excess of acid, I suspected that this excess only might produce the precipitation with lime-water, and that the neutral compound might remain entire ; but I decomposed the whole with a sufficient quantity of lime-water, and nothing but an alkaline liquor was left. Phosphorated lime is indeed precipitated by alkali, but not in consequence of a superior elective attraction. This salt is not soluble in water without an excess of acid ; and whatever takes away the medium of solution, as in the present case the alkali does by saturating it, causes a precipitation of phosphorated lime : aerated alkali, however,

ever, decomposes it by means of a double attraction; and aerated lime falls down, (IX.). In ambiguous cases of this kind, we must form our conclusion from the decomposition of that salt which is more easily soluble. Thus, the present question is answered by the precipitation of phosphorated alkali by lime-water, and not by that of phosphorated lime by alkali. The superior power of magnesia and terra ponderosa, is not yet ascertained with so much certainty.

IN the dry way, I place lime before magnesia and ponderous earth, since the former undoubtedly dispossesses fixed alkalis, which is not yet certain concerning the latter.

XXXIV.

Column Twenty-third, Acidum Perlatum.

IN 1740, Haupt found a salt in human urine, and described it under the title of *sal mirabile perlatum*; it is the same which Margraaf mentions as altogether unfit for generating phosphorus with powdered charcoal. Nevertheless, many have supposed, that this salt, which occurs in urine with the microcosmic salt, contains the phosphoric acid, and have explained its rejection of phlogiston from the superior attraction of fossil alkali. But Mr Proust has lately disengaged the substance, which alone performs the office of an acid in *sal perlatum*; in microcosmic salt, indeed, it is united with the phosphoric acid. He digested *sal perlatum* in distilled vinegar, brought it to afford crystals, and precipitated from the mother ley, by

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spirit

spirit of wine, a thick liquor, which, after being well washed in spirit of wine, and then dissolved in distilled water, yielded an acid * which I call the *perlate*, till a more accurate examination shall suggest a better name. Mineral alkali, if I mistake not, covers the acid. The crystallization, taste, reaction, and efflorescence, point out an excess of alkali. Perhaps this excess prevents spirit of wine, which rejects no acid, from extracting the acid part. It fuses with ebullition, and appears pellucid, but when cooled it becomes opaque: it is taken up by acids, and may be separated by spirit of wine: it exists with the phosphoric acid, as well in bones as in microcosmic salt.

It certainly prefers lime, ponderous earth, and magnesia, to alkalis. With mineral alkali, it regenerates sal perlatum.

It

* Rozier's Journal.

IT would be a peculiar and highly remarkable phænomenon, if a neutral compound, by means of an intimate union with phlogiston, could act as an acid without decomposition. This, however, seems to be the case with sedative salt, and still more certainly with the acid of Prussian blue, which will be described below. That obtainable from sal perlatum, is, if I mistake not, of the same nature. By means of a strong impregnation of phlogiston, it is so closely combined with a certain portion of fossil alkali, that we have not as yet been able to effect a separation of the principles; and what well deserves notice, the compound, as a simple acid, takes up alkalis, earths, and metals, though several properties plainly indicate an excess of alkali. Meanwhile till their nature is better ascertained, I consider them as acids, since they seem to approach nearest to these substances.

XXXV.

Column Twenty-fourth, Acid of Prussian Blue.

I HAVE long conjectured, not without reason, that the tinging matter in Prussian blue is of an acid nature, as it forms compounds of an intermediate kind with alkaline salts, as well as with earths and metals. Mr Scheele has lately taught us how to separate the acid in a pure state*. Phlogisticated alkali, as it is commonly called, is a triple salt; containing the tinging acid, saturated partly with iron, and partly with alkali. This salt, boiled in a retort with weak vitriolic acid, emits the tinging acid in an inflammable aerial form, which may be absorbed by water placed in the receiver. And as at the same time, some vitriolic acid passes

* Act. Stockh. 1782.

passes into the receiver, the liquor should be again distilled with a little chalk, till one-fourth shall have passed over; which is a solution of the present acid in water. The following process answers the same end with less trouble: let sixteen parts of Prussian blue be boiled in a cucurbit, with eight of mercury, calcined by means of nitrous acid, and forty-eight of water, for a few minutes, with constant agitation. The mixture becomes of a cineritious yellow; it should be put on the filter, and the residuum elixated with boiling water. To the filtered liquor, let twelve parts of pure iron filings be added, and three of concentrated vitriolic acid. After a shaking of some minutes, the whole mass is turned black by the reduced mercury. After the subsidence of the powder, the clear liquor is to be decanted into a retort, and one-fourth abstracted.

THIS acid, in some respects analogous to the perlate, is distinguished by a peculiarly disagreeable taste and smell, and consists of aerial acid, volatile alkali, and phlogiston. It speedily flies off in an open vessel: it seems to prefer alkalis to earths. Its forcible attraction for metals will be more particularly considered in the sequel.

XXXVI.

Column Twenty-fifth, the Aerial Acid.

OF this acid, which is common to all the kingdoms of nature, I have treated at length in another essay, and have particularly examined its attractions in § 20. *. I shall now add only a short comparison of it with phlogisticated vitriolic acid, since they are wretchedly confounded by some, who find it more easy

* Opusc. vol. i. p. 43.

easy to burden natural philosophy with feigned hypotheses, than to enrich it with accurate experiments. I have said above, that phlogiston, united with vitriolic acid, in different proportions, produces either vitriolic acid air, which, when absorbed by water, is called phlogisticated vitriolic acid, or sulphur, (XIII.).

PHLOGISTICATED VITRIOLIC ACID has a most penetrating smell ;—saturated with vegetable alkali, generates the sulphureous salt of Stahl ; the crystals spiculæ indistinctly hexangular ; — they detonate with nitre ;—may be totally sublimed by a proper application of heat ;—do not effervesce with other acids ; — gradually lose their phlogiston, and are at last spontaneously changed into vitriolated tartar.

THE AERIAL ACID has no smell ;—with vegetable alkali, forms aerated alkali ; the crystals quadrangular prisms ;—they do not yield a spark with nitre ;—are fixed ;—emit constant numberless air-bubbles, till the saturation is complete, even with phlogisticated vitriolic acid, to which the aerial acid is inferior in attractive power ; — remain unchanged, unless fire or some stronger acid expel the weak aerial acid.

HENCE let those who are skilled in chemistry, and regard truth, form a judgment. If any one supposes other combinations of vitriolic acid with phlogiston, besides those mentioned above, he must prove the mode of their formation, not by opinions, but by experiments.

A SIMPLE experiment proves that the aerial acid is attracted by atmospheric air; for if a phial filled with the former be set in an open place, where the ambient fluid undergoes no agitation, it will be found to contain atmospheric air only. Nay, aerated water yields its volatile acid to the atmosphere.

XXXVII.

Column Twenty-sixth, Caustic Vegetable Alkali.

HAVING examined the attractions of the acids, we now come to the alkalis, which are commonly combined with aerial acid, but when freed from this, are called caustic, or even pure ; and it is in this state only that they can be employed for the present purpose, for, when aerated, they give rise to double affinities ; see Schemes 1—8. 32—36. 46. 51. 62. and 63. Those which are properly called saline, are of three kinds. The first is denominated vegetable alkali, being all obtained from this kingdom ; and of this only I shall speak in the explanation of column twenty-sixth.

THE

THE vegetable alkali adheres most strongly to vitriolic acid, for it not only is not dislodged by either of the others, but takes this acid from them. In what manner nitre and sea salt effect a partial decomposition of vitriolated tartar, and the acid of tartar, likewise of nitre and digestive salt, I have explained above, (IX.), and in Scheme 9. 10. and 11. have symbolically represented the partition of the acid by darts.

THE second place belongs to the nitrous, (VI.), and the third to the marine acid. Whether the aeriform muriatic acid is capable of decomposing nitre, has not been sufficiently tried. In order to account for the order of the other acids, it will be proper to mention the chief experiments,

THE celebrated Crell has admirably shewn, that the acid of fat is neither
expelled

expelled by the acids of fluor nor of phosphorus. That of fluor dropped into a solution of phosphorated vegetable alkali, immediately precipitates a triple salt, consisting of fluor acid, vegetable alkali, and flint *. I dropped arsenical acid into a solution of phosphorated vegetable alkali; after the mixture had stood twenty-four hours, spirit of wine precipitated the phosphoric salt in no respect altered, and the acid of arsenic remained in the spirit. Therefore the phosphoric is the stronger. The acid of tartar decomposes all the salts which contain vegetable alkali, as far as I have tried, as the combinations of this basis with the vitriolic, nitrous, marine, saccharine, phosphoric, and arsenical acids, some completely, but others only in part, (IX.). To discover, therefore, its real power, acid of tartar should be dropped into solutions of mineral alkali, combined with the several acids,

* Opusc. vol. ii. p. 34. 37.

acids. For this alkali attracts the acids in the same order as the vegetable, without acquiring any excess, by which the observer might easily be misled. The acid of sugar seems more powerful than that of tartar; those of sorrel, lemon, and amber, weaker; but their order with respect to each other has not yet been sufficiently ascertained. Next follow the acids of ants, milk, and benzoïn, which are stronger than vinegar. Acid of borax is expelled by vinegar, as also the perlate acid, the nitrous and vitriolic fully phlogisticated. The aerial yields almost to all; it however precipitates solutions of flint, sulphur, and oil; it even expels the acid of Prussian blue. Vegetable alkali takes up copper and tin, but their places are uncertain.

IN the dry way, the acids of phosphorus, borax, arsenic, and perlatus, are superior on account of their fixity,
(IV.):

(IV.): the rest, except those that are destroyed by strong heat, observe the same order as in the moist way. Pure earths coalesce with alkalis in heat, but in what order is uncertain; nor can it be easily ascertained, since when any one is united by fusion with alkali, it is not precipitated by the addition of another, but both combine with the menstruum, and form an homogeneous mass. The same thing holds with respect to sulphur.

XXXVIII.

Column Twenty-seventh, Caustic Mineral Alkali.

THIS fixed alkali has received the name of mineral, from the great quantity of it which occurs in the mineral kingdom; it is also found in plenty in some vegetables growing in the sea,
or

or in a salt soil. It differs from the preceding, being both weaker, (XII. XIV. XVI.), and generating different salts with the same bases. The acid of tartar does not in any respect change sea salt, (Scheme 12.), which affords an easy method of distinguishing it from digestive salt. For the acid of tartar is the best test yet known for detecting the presence of vegetable alkali in any mixture, as it decomposes all the salts which have this basis, some totally, others only in part, (IX.). This decomposition is denoted by the deposition of tartar, which, if the dose of alkaline salt be considerable, and the solution concentrated, becomes perceptible in an instant: a smaller quantity, especially in a weaker solution, requires the space of a day or two.

As to the order of attractions represented in this column, I have not found it to differ from that in the thirty-seventh.

seventh. This acid more certainly shews the true order with respect to acid of tartar, and in certain cases more distinctly, as the compounds are more difficult of solution than those containing the vegetable alkali. This is often advantageous in determining the attractions. Scheme 13. shews the decomposition of borax by nitrous acid; Scheme 42. of sea salt by the same, and 43. by acid of arsenic.

XXXIX.

Column Twenty-eighth, Caustic Volatile Alkali.

THE order of attractions for acids seems to be the same in this instance as that of the fixed alkalis; but the volatile alkali takes up several metals, which are left untouched by the others.

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That zinc precipitates the other metals, when dissolved in volatile alkali, is certain, (Scheme 18.), and for the same reason as those which are dissolved in acids; a reason that has been formerly mentioned, and will be farther illustrated hereafter, (XLVII.); on this account I have placed them in the same order as in the columns of the acids, till experiment makes us acquainted with a better.

THE influence of phlogiston on the solution of metals in acids, has been shewn above in various instances, (V. XIII. XV. XVII.); let me now consider some combinations of volatile alkali. To caustic volatile alkali let some filings of copper be added; if the phial be quite full and be immediately stopped, no solution will take place, but if a little space above the liquor be left to the air, or the phial remain open for a quarter of an hour, in a few days a solution

solution will be obtained as colourless as water ; but if the stopple be taken away, it soon grows blue at the surface, and the same tinge gradually pervades the whole mass. A solution thus coloured may be soon procured in an open phial. The solution loses its colour, if new filings be added, and the phial be kept closed for twenty-four hours. These remarkable variations depend on phlogiston: copper is insoluble in its metallic form, but it is very soluble when a little of the inflammable principle is extricated. Such a privation is effected in a vessel, either open, or only filled in part, by means of the air which strongly attracts this principle, as will be shewn hereafter, (XLVII.), and the effects will vary in proportion to the quantity. If just as much is carried off, as is necessary to render the copper at all soluble, the solution will be colourless ; but if it be farther deprived of phlogiston, the calcined copper

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yields

yields a blue solution, which is obvious even to the eye, for the colourless solution is soon deprived of phlogiston, by being exposed to the air, and therefore immediately begins to turn blue, upon coming into contact with the air. On the other hand, the blue solution loses its colour, in the way above mentioned, since the alkali more willingly attacks copper but a little dephlogisticated, than that which is much calcined. The force with which volatile alkali attracts dephlogisticated copper, promotes the effect of the air.

VOLATILE alkali detonates with nitre, whence it manifestly appears to contain phlogiston, and that as a proximate principle, which is separated by the calx of manganese, quicksilver, gold, and various other substances, in consequence of a stronger attraction; and then an elastic fluid, of a peculiar nature, is obtained, which probably is
the

the other principle: I say *probably*, for it has not yet been reduced to volatile alkali by the addition of phlogiston. Moreover, in this decomposition it deserves to be remarked, that no signs of vegetable alkali occur, since many contend that the volatile originates from the vegetable, intimately combined with phlogiston.

IN the dry way, the attractions of volatile alkali seem to differ from those immediately preceding in this, that it may be expelled by fire alone, when united with certain fixed matters; and on this account I have thought proper to exclude them entirely.

XL.

Column Twenty-ninth, Caustic Ponderous Earth.

THE celebrated Margraaf asserts that the base of ponderous spar is calcareous earth, and indeed experiments shew that they agree in various properties; but Dr Gahn and Mr Scheele, by a more particular investigation, detected a great difference between them, and from my experiments it appeared to be still greater. Both agree in effervescing in acids; in losing the aerial acid, when exposed to fire, and thus acquiring solubility in water, and affording a cream in the open air; in rendering alkalis caustic, and in dissolving sulphur, &c. But they differ widely at the same time; for gypsum is lighter, and totally soluble in water, but ponderous earth forms with the vitriolic acid ponderous

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ous spar, of which the specific gravity is 4,500, and which can scarce be at all dissolved in water; with nitrous and marine acids lime forms only deliquescent salts, but ponderous earth difficultly soluble crystals; lime saturated with acetous acid affords crystals, but ponderous earth an almost deliquescent salt: finally, they differ widely in their attractions, as is evident from the preceding observations, and will now be made to appear more clearly.

THIS earth is but sparingly scattered over the surface of the earth, and has hitherto been found only in combination with the vitriolic acid; a combination so close that it can solely be destroyed by the phlogiston of oils and charcoal, with the assistance of fire, and then with difficulty. To obtain it pure, it should be afterwards dissolved in nitrous acid, and precipitated by aerated

fixed alkali, which is effected by virtue of a double elective attraction, for it cannot be dislodged by caustic fixed alkali, (XIV.).

PONDEROUS earth forms, with most acids, salts of difficult solubility. From all, the smallest drop of vitriolic acid immediately throws down ponderous spar in the form of powder; wherefore I know nothing better than a solution of this earth, in acetous or marine acid, for detecting the faintest traces of vitriolic acid, for it takes it from every other basis.

THE acid of sugar occupies the next place. If it be dropped into a saturated solution of ponderous earth, in the nitrous or marine acids, it separates, in a few minutes, pellucid crystals, consisting of the earth combined with the acid that was added. The same acid decomposes the compounds formed of
terra

terra ponderosa, and the acids of amber, of fluor, phosphorus, of the perlate, and that of sugar of milk, which are all stronger than the marine acid.

THE acid of amber comes into the third station; that of fluor into the fourth, for it precipitates solutions made by acids of amber, fluor, forrel, phosphorus, of perlate salt, nitre or sea-salt; and lest any one should ascribe this to the presence of vitriolic acid, let it be observed that this sediment, when collected and added to vitriolic acid, gives out fluor acid.

THE acid of forrel expels the phosphoric and perlate acids, that of sugar of milk, nitre and sea-salt, and forms a compound scarce soluble, which come next. The strength of the sebaceous acid has not yet been determined; in the mean time I have placed it after the marine. The remaining form this series: acid of lemon, tartar, arsenic,

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ants,

ants, milk, benzoin, vinegar, of borax, of vitriol and nitre phlogisticated, the aerial, and that of Prussian blue. The relative situation of the first mentioned individuals wants confirmation. Acid of arsenic does not visibly render acetated ponderous earth turbid, but seems to form a triple compound; it, however, palpably expels the acid of benzoin.

I CONJECTURE, that, in the dry way, our earth comes next to the fixed alkalis; but I exclude the other earths, since the ponderous scarce fuses with them. Besides, I have subjoined fixed alkali, and calx of lead, since it enters into fusion with these.

XLI.

Column Thirtieth, Lime.

PURE calcareous earth, or lime, in the strict sense of the word, is that which is free from every heterogeneous substance; but by this appellation I indicate the absence of acids, especially the aerial. Its attractions are very different from those of ponderous earth. The first place belongs to acid of sugar, which takes lime from every other, (Scheme 14.). To this succeeds acid of sorrel, which decomposes even gypsum, by attracting its basis. Vitriolic acid exceeds the nitrous, and the others, (Scheme 16.). Acid of tartar takes lime from that of amber, the phosphoric, perlate, and the following; and in like manner phosphoric acid, the perlate, and that of sugar of milk, from the nitrous, marine, fluor, arsenical, of
ants,

ants, milk, lemon, and vinegar. Fluor acid attracts lime more powerfully than that of ants and vinegar ; but is scarce superior to the nitrous and marine, unless by the aid of water, and a double attraction. Acids of lemon and ben-zoin exceed vinegar. The arsenical acid does not disturb formicated and acetated lime, unless the solution be concentrated. The place of the sebaceous is still uncertain. The last individuals follow the order of the preceding column.

WHAT is said in the preceding paragraph may be applied to the attractions of lime, magnesia, and clay, in the dry way, except that the last scarce attacks sulphur.

XLII.

Column Thirty-first, Caustic Magnesia.

THIS salt, which is called in the shops *magnesia alba*, differs in various respects from lime, as I have shewn in a particular essay. I once thought, that this earth attracted acid of fluor most forcibly, and that all others were expelled by it, (Scheme 15.); but the repetition of the experiments gives room to suppose that I was misled by the siliceous sediment: I therefore assign the first place to acid of sugar, and so on as in the column; of which the order is for the most part established by experiments, in the dissertation above mentioned. Some places are, however, uncertain, especially those occupied by the acids of sorrel and lemon. Calcin'd magnesia is insoluble in water, which

which is a great obstacle when we are endeavouring to ascertain attractions.

XLIII.

Column Thirty-second, Pure Clay.

UNDER this denomination I understand earth of alum well purified, for common clay is always more or less mixed with the filiceous in powder: it contains, however, the real basis of alum, and thence derives its peculiar properties.

THE vitriolic acid attracts clay more powerfully than any other, next the nitrous, and then the marine acid. The order of the rest is not sufficiently ascertained; it is, however, certain, that the acids of fluor, arsenic, sugar, tartar, and phosphorus, take clay from the acetous. The determination of the attractions is in this case prevented, not only

only by the infolubility of pure clay, as in the case of magnesia, but likewise by the obscure cryftallization or deliquescence of the compounds, which commonly conceal the decomposition.

XLIV.

Column Thirty-third, Siliceous Earth.

WHILST the vitriolic expels from fluor its proper acid, the surface of the water in the receiver, even in the gentlest heat, is gradually covered with a white powder, which soon forms a crust. When this is broken, and sinks, another is generated, and so on, as long as any acid of fluor passes over. This matter, when collected and washed, has all the properties of siliceous earth. I collected a parcel, and sent it to Mr Macquer, who assured me that it had all the properties which siliceous

liceous earth shews in the focus of a burning glass. Now, whence comes this powder? Does it exist in the fluor, and is it volatilized by the heat? Or is it extracted from the glass? Or is it formed from its principles?

I BY no means deny, that fluor sometimes contains siliceous particles, but they are accidentally present; for that of Garpenberg, which I generally used in this operation, sometimes contains not a particle. This, when reduced to the finest powder, is totally soluble, by a long digestion, in aqua regia, which would never happen if it contained flint. Hence, therefore, it is evident, that siliceous earth enters the composition accidentally, and that the powder collected in the receiver is by no means to be ascribed to it, since no such substance exists in the compound. But perhaps other specimens from Garpenberg are more or less mixed

ed with it. Glafs indeed abounds in filiceous earth, and is corroded during the procefs ; but as Mr Scheele ſaw the powder appear when metallic veſſels were uſed, I have long thought that in this experiment there was a generation of filex. Into a phial of iron or copper, upon which concentrated vitriolic does not act, there was put fluor mineral in powder, with an equal weight of ſtrong vitriolic acid ; the cover was then applied, to which were faſtened below ſeveral different bodies, ſome dry, and others wet. The phial was expoſed for ſeveral hours to a gentle heat of digeſtion, and upon opening it all the moiſt ſubſtances were found to be covered with powder, and the dry ones quite free from it. But the fluor uſed in this caſe, without doubt, contained filiceous earth ; for Mr Meyer has ſince found, by accurate and well conducted experiments, that no filiceous powder appears in metallic veſſels
when

when no glass is used. The fluor with vitriolic acid yielded nothing; but the same mixture, in equal quantity, set in a metallic vessel, when glass was added to it, swelled very much, and a siliceous powder was volatilized. The fluor acid, therefore, when resolved into vapour, seizes siliceous earth with violence, extracts and retains it till it is absorbed by water; for upon entering into this new combination, it is forced to deposit part of the flint: the rest remains dissolved in the acid liquor, and may be thrown down by alkaline salts *. But no other acid is capable of dissolving siliceous earth, not even in the very tender state of a precipitate, from liquor silicum †.

FIXED alkalis, especially when caustic, dissolve very fine siliceous powder in
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* Opusc. vol. ii. p. 34.

† *Ibid.* p. 36. and vol. iii. p. 314.

the moist way, but far more plentifully in the dry. All the acids, not even the aerial excepted, effect a separation.

LIQUOR silicium is precipitated even by fluor acid; but the powder which falls does not consist of pure siliceous earth, for it contains likewise fluorated alkali, and thus exhibits a triple salt.

WATER entirely rejects filix in a moderate temperature. I always procure by evaporation a small portion of siliceous earth from the water of the Upsal springs, notwithstanding it has passed through the filter several times; but it without doubt is so fine, as when once mixed with the water, to be retained by friction; for division increases the surface, and with it the friction, which at last becomes equivalent to the difference of specific gravity.

IN the dry way, siliceous earth is fusible with borax, minium, and other
N proper

proper substances, but most easily by fixed alkali.

SOME of the moderns reckon *earth of ivory* among the simple earths, but improperly, for it is doubtless a compound, and, like earth of hartshorn, contains both aerated and phosphorated lime.

XLV.

Column Thirty-fourth, Water.

SINCE sand in a very attenuated and volatile state preserves a level, so that animals may be drowned in it; since pounded gypsum set in a kettle over the fire seems liquid, not to mention other instances, why may not liquids in general be considered as solid molecules too subtle to be perceived by the sight, however assisted, and on account of their levity, bulk, figure, or by the interposition of another fluid, moveable
with

with the greatest ease, and affecting an horizontal surface? Hence water would seem to be nothing but earth kept liquid by heat. It certainly concretes into a solid body when the heat is diminished to a determinate degree; but when the heat is increased to a certain term, it is resolved into elastic vapours.

EVERY particle having a certain force of attraction for the principle of heat, forms a little atmosphere for itself. As long as these atmospheres prevent the particles from coming into contact, the whole remains liquid; when they are enlarged, the distances increase, and an expansion takes place, till at last the superficial particles are resolved, by the necessary quantity of heat, into elastic vapour. At 212° the whole mass undergoes this change. The vapours then arise in great abundance, and produce the agitation of boiling. They exceed the bulk of the water 14,000 times,

and then the vast surface is able to absorb a far greater quantity of heat than before ; and is it not thus that all evaporation produces cold ? On the other hand, the excess of heat being gradually diminished by the coolness of the air, or in any other way, the bulk of the vapours is contracted, and they are condensed at last into drops of water. If the matter of heat goes on to decrease, the particles drawing near to contact lose their respective mobility, and concrete into ice. What is hereafter to be said on the subject of specific heat, will farther illustrate these remarks, (XLVIII.).

SALINE, gummous, and spirituous substances are especially soluble in water. In what order the salts are taken up, has been hitherto little examined, nor is this an easy task. Concentrated vitriolic acid takes water from a solution of vitriolated vegetable alkali, of alum, vitriol,

vitriol, corrosive sublimate, and other substances, which it does not decompose, so that they crystallize almost instantaneously. The other acids scarce exert this power perceptibly.

CAUSTIC alkalis likewise attract water strongly, and precipitate various salts which they do not decompose.

WATER attracts spirit of wine more forcibly than those salts which are insoluble in spirit of wine, and which therefore may be precipitated by it. This is the case with volatile alkali, which, when thus precipitated, is called *Van Helmont's soap, Sapo Helmontii*.

THE elective power of water with respect to neutral and middle salts is hitherto unknown, and has been totally neglected. It is, however, probable, that each is attracted with unequal force, and that one gives way to another.

ÆTHER may in some measure be separated from spirit of wine by water.

XLVI.

Column Thirty-fifth, Vital Air.

A.] The atmosphere which every where surrounds our globe, consists of a pellucid, elastic, and apparently homogeneous fluid, which we denote by the name of *common* or *atmospheric* air: when more closely examined, it is found to contain, besides vapours which vary wonderfully, according to the diversity of situations and winds, three fluids mixed together, and widely differing in their nature. The greatest part, which certainly exceeds the others three times or more in bulk, is neither fit for supporting fire, nor for respiration, probably derives its origin from the vital
part,

part, in consequence of some change not yet certainly known, perhaps proceeding from the addition or subtraction of phlogiston, and may therefore be called *corrupted* air. That which in England is called *dephlogisticated*, and which I have formerly termed uncombined, good or pure, but now think with the historian of the Parisian Academy, that it should be distinguished by the appellation of *vital*; this, I say, differs widely from the preceding, being not only fit, but indispensably necessary for fire and respiration, every other air being mephitic. The aerial acid forms the smallest part of the atmosphere, scarce ever amounting to one-sixteenth.

B.] Vital air is found but sparingly mixed with the atmosphere, amounting scarce to one-fourth of its bulk, seldom or never exceeding one-third, as I have just intimated. It may, however, be

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obtained

obtained by various means. An ounce of nitre, exposed to heat in a pneumatic apparatus, affords 500—600 cubic inches of air, far better, especially at first, than common air. Nitrous acid poured upon many metals and earths, and then abstracted to dryness, yields first nitrous air, if any phlogiston be present, and then more or less of vital air. Vitriol of iron, copper, and zinc, and various vitriolated earths, nay, lapis calaminaris, manganese, and the calces of the noble metals acquired by precipitation, afford, when exposed to a due degree of heat, a portion of vital air during their reduction. Hence it may be justly concluded, that this air can indeed be obtained without nitrous acid, but that by means of it a much larger quantity is procured, so that it is scarce to be doubted but that it enters as a principle into the acid, or the acid into it. In the former supposition, something must be removed, which
when

when again added to the vital air in proper quantity, must impart to it, besides other properties, a strong acidity. The nature of this is unknown. Nitrous air alone is at least insufficient, unless the existence of phlogiston be denied, which, however, would be contrary to evident experiments; nor does it seem to be the inflammable principle, by which, on other occasions, all the acids are debilitated, and, when fully saturated, are as it were fettered. It should, however, be remembered, that compounds sometimes have properties not belonging to either of the ingredients. But in the case in question, this bare possibility is unsupported by any experiment, which shews that distinct acidity proceeds from phlogiston. The latter proposition is countenanced by the following considerations. It appears from experiment, that nitrous acid very forcibly attracts phlogiston, is rendered much weaker

weaker by it, and at length, by the aid of a certain portion of the matter of heat, acquires an aerial form, being changed into the aeriform nitrous acid: with a greater portion of phlogiston, nitrous air is formed, containing the acid saturated; may not, therefore, a farther addition of phlogiston or specific fire, as the increase of weight seems to indicate, or both these causes, produce a new variation, and may not this be vital air? This opinion is, however, liable to difficulties, which shall be mentioned in the sequel. Meanwhile, granting these positions, and assuming Mr Scheele's hypothesis, the phænomena accompanying its generation admit of a consistent explanation. We know that the acid as present in nitre may be phlogisticated by fusion. The cohesion is diminished in proportion to the increase of phlogiston, and by a certain quantity is totally destroyed, so that it is changed into vital air, and may be expelled

expelled by heat. The accession of phlogiston is derived from the decomposition of heat; now, by the separation of one principle, the other which is left uncombined, according to the hypothesis, is vital air, and which therefore comes from two sources, composition and decomposition. If these things be true, we can easily comprehend how it is obtained from nitrous acid, poured upon almost any substance; and also how we come to procure a new portion, by adding fresh nitrous acid, when the former portion has been exhausted. So great is the volatility of this acid, that it escapes before it is sufficiently concentrated to receive phlogiston; the basis fixes the acid, and when it contains phlogiston, contributes, at the beginning of the process, while the heat is moderate, to the production of nitrous air.

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THE substances which furnish vital air without nitrous acid, contain, for the most part, some metallic principle, which, when acted upon by a strong fire, decomposes either their inherent specific heat, or that which flows in through the vessels. The noble calces seem by these means to be reduced to a metallic form, without the addition of phlogiston, even such as neither receive any aerial acid, nor contain any nitrous air, as gold dissolved in dephlogisticated muriatic acid, and afterwards precipitated. The ignoble calces of lead, iron, zinc, manganese, and perhaps others, are also capable of decomposing heat, but cannot retain a quantity sufficient for their reduction. Manganese does not indeed grow black from the action of heat alone; but by the assistance of vitriolic acid, it fixes a quantity sufficient to render it soluble. Such phænomena sometimes, though rarely, occur in the
humid

humid way. Upon minium dephlogisticated, by a long continued calcination, and put into a small retort, let a little more than its bulk of concentrated vitriolic acid be poured; the mixture soon grows warm, and acquires a black colour, a phænomenon which is produced by heat alone; then some degree of effervescence takes place, during which, some aerial acid is extricated; but in a minute or two the heat becomes insupportable to the touch, and at the same time there issues out with vehemence a white smoke, which yields pure vital air: the volatilization of the powder gives it at first the appearance of smoke. The addition of pulverized glass renders minium more penetrable to the vitriolic acid; without this addition, the upper stratum of the mass grows white, while the lower strata still remain black, or are not yet acted upon by the acid; in which case, aerial acid is extricated during the whole time of
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the production of any elastic fluid. I have treated minium in like manner with the muriatic acid; but in this operation the menstruum must be made to boil. Then aerial acid is extricated, as also dephlogisticated marine acid, and the vital air scarcely amounts to one-fourth. I have no doubt of the existence of aerial acid in the minium; but it remains to be tried, whether it be present in minium recently prepared. I cannot determine this, since it is not made in Sweden. It probably does not unite with the lead during calcination, but is afterwards attracted from the atmosphere, as happens with regard to lime. But the origin of the vital air is an important enquiry. Some deduce it from the dephlogistication of the aerial acid; Mr Scheele from the decomposition of heat. All minium, hitherto examined, contains a small portion of magnesia nigra, which is capable of decomposing the matter
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of heat, and lead may perhaps have the same power. Muriatic acid is more easily decomposed; and therefore, by employing this menstruum, we gain but little vital air. Aerated lead, treated in the same manner, yields only aerial acid; but nitrated mercury, calcined to redness, and the spontaneous sediment of vitriolated iron, when treated with vitriolic acid, produce nearly the same effects as minium. Iron is scarce ever without manganese, and seems itself capable of decomposing heat; for that which is not magnetic, acquires this property in the crucible without any addition of phlogiston.

THE great specific heat of vital air, which can be shewn by proper experiments, renders its origin from nitrous acid, by the addition of phlogiston, not a little suspicious; and perhaps future experiments

experiments will shew that it is not the real one.

C.] The relation of vital air to other bodies is now to be considered. There is no substance hitherto known, on which vital air acts more readily and efficaciously, than on nitrous air. At the instant of contact, the whole mass almost hisses, turns red, grows warm, and contracts in bulk. The enquirers into nature are not yet agreed about the cause of these phænomena. There are two prevailing opinions, of which one will probably prove true. Mr Kirwan has thus explained it *. Phlogiston is more strongly attracted by vital air than by nitrous acid; wherefore the nitrous air is dephlogisticated, loses its nature, and the red vapour of nitrous acid is produced, which water readily absorbs. But vital air, saturated with phlogiston, forms aerial acid, and

* Phil. Trans. 1782.

and with a still larger portion is converted into corrupted air. The bulk is sometimes diminished to $\frac{3}{10}$, in consequence of the destruction of the nitrous air, and the generation of aerial acid, which being heavier than the vital air, and having less specific heat, ought necessarily be contracted, and, moreover, may be totally absorbed by water. The incallescence is produced by the destruction of the nitrous air, which, as well as the phlogisticated vital air, parts with a portion of specific heat. This is a very ingenious explanation; but before it can be received as quite satisfactory, so much aerial acid, as it supposes, must be more precisely demonstrated. If I mistake not, the production of aerial acid is deduced from the precipitation of lime-water, and its quantity from the diminution of bulk. With respect to the former conclusion, it is well known that lime-water is manifestly rendered

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turbid by a very small quantity of aerial acid, accidentally mixed with vital air ; but the diminution, if it be repeatedly passed through recent lime-water, may arise from another cause, for water absorbs one-fourteenth of its own bulk of vital air ; if, therefore, a sufficient quantity of water be present, the whole diminution may happen in this manner. In Mr Scheele's hypothesis, the relation of vital to nitrous air is also made to consist in the dephlogistification of the former ; but it is said, that the matter of heat is generated by this combination, which, in the present case, is not absorbed by any of the surrounding bodies ; for the nitrous air changing from fluidity to a liquid state, must give out a portion of specific heat, to be distributed among the contiguous substances, and evidently passing through glass. On what foundation this origin of heat rests, I shall hereafter examine, (XLVIII.).

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THE inflammable air of metals contains phlogiston almost pure, in an aerial form ; yet it neither changes vital air, nor is changed by it, not even when the surface of contact is increased by the accession of external heat ; a circumstance which seems ill to agree with what has been just said of nitrous air. But it is to be observed, that the decomposition of nitrous air is the effect of a double attraction ; the phlogiston is attracted by vital air, and the acid part by water. Therefore, when the mixture is made in a phial immersed in mercury, the experiment fails. But the contact of flame, or a glowing body, produces a wonderful effect in the mixture of inflammable with vital air ; for it takes fire with so much violence, as far to exceed common fire in heat and efficacy, and to dazzle the eyes with the brightness of the light. If the conflagration be performed in a space closed by mercury, as may be done by

prudent management, the whole bulk of air is found to have in great measure disappeared after the extinction of the flame, and the cooling of the apparatus. The residuum affords corrupted air, scarce ever mixed with aerial acid. This diminution is explained, as before, in two ways. It is impossible to deny, that a contraction of bulk must take place, if vital air be changed, by combination with phlogiston, into aerial acid, which is heavier, and has less specific heat; but the farther change of aerial acid by phlogiston into corrupted air, a lighter substance, and therefore necessarily occupying a larger space, seems ill to agree with the small portion which remains after deflagration, though even the whole of the inflammable air should become fixed.

If we suppose both airs perfectly pure, this inflammation would seem the most simple of all; for there is no superfluous principle present, either to
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give out any extraneous fluid during the operation, or to yield any residuum which greedily absorbs a portion of the mixture.

ELECTRIC sparks seem to come nearest to this operation ; they may be considered as small flames changing the vital air which they meet with on the surrounding medium, by means of their phlogiston, either into aerial acid or heat, as must be determined by future experiments. Alkaline air is changed by the electrical spark into inflammable air of thrice its bulk, which sufficiently shews that these sparks give out phlogiston in a free and elastic state.

IN vital air, without the aid of external heat, phosphorus is consumed very slowly, and scarce at all, unless water be present to forward the decomposition, by a double attraction. It may be burned by proper management in a glass vessel closed with mercury.

The method that best succeeded with me, was to introduce a small piece into the glass vessel, and set fire to it, by applying the flame of a candle externally. This was repeated as long as the bits successively introduced could be made to deflagrate. After the apparatus had grown cool, there never remained above one-fourth, often not above one-tenth of air, and sometimes still less; the residuum consisted of corrupted air, very seldom mixed with aerial acid. Here the hypothesis, concerning the origin of the aerial acid and corrupted air, from the phlogistication of the vital, seems scarce admissible. We have in this experiment no uncombined phlogiston, by consolidation of which the bulk might be diminished. The difficulty is, however, lessened, by the absorbing power of the uncombined phosphoric acid, of which more will be said hereafter. Sulphur may be burned
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in the same way, and exhibits almost the same phænomena.

THAT kind of inflammation is most complex, which consumes a body that gives out aerial acid from its own substance, and at the same time yields an absorbent residuum. To this head belongs the combustion of pyrophorus, candles, and other animal and vegetable substances. There can be no inflammation without vital air, whence it may be considered as the pabulum of fire; yet the phænomena vary according to the nature of the bodies to be consumed. It is asserted, that in a space limited by mercury, a candle which is left to burn as long as it can, diminishes the air little or none; and it is certain that the bulk is found the same after cooling, for the consumed fat yields a quantity of fluid nearly equal to the vital air consumed by the flame. It is known that

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oils,

oils, when decomposed in close vessels by fire, gives out aerial acid.

HEPATIC air, dephlogisticated by vital, deposits sulphur but slowly ; whereas nitrous air is decomposed at the moment of contact.

METALS, being loaded with phlogiston, cannot but be exposed to the power of vital air. The ignoble ones are decomposed more or less quickly, according to circumstances ; the noble resist obstinately : however, the purest gold, when fused, and sufficiently rarefied by the focus of a lens, is forced to part with some of its phlogiston*. Mercury, which seems intermediate between the noble and the ignoble, when sufficiently heated, is well and quickly calcined in vital air, but remains unchanged in corrupted air, as Dr Priestley has found. I have experienced the
same

* Macquer Dict. de Chimie.

same thing with that mixture of lead, tin, and bismuth, which is fusible in the heat of boiling water. The effects are here also explicable from the generation of aerial acid, or the matter of heat. On the former supposition, a difficulty arises from the rejection of aerial acid by many metallic calces, and from the reduction of gold without addition, when it has been dissolved in dephlogisticated marine acid, and precipitated by alkali, when the calx is neither contaminated with aerial acid nor nitrous air. By Mr Scheele's system, these difficulties are avoided, but others occur not easily to be obviated by the decomposition of heat. The calcination of lead by mercury in common air *, which is diminished one-fourth, and yields an aerated calx, is among them; for I have never found in common air a quantity of aerial acid amounting to one-fourth of common air, nor, I believe,

* Mr Kirwan,

lieve, has any one else: it remains, however, to be tried, whether the bulk of the aerial acid, when expelled, corresponds to the above-mentioned diminution. The increase of weight is ascribed, with great probability, to aerial acid, when it is present; but I can scarce doubt that something is contributed by the increase of specific heat. Nor is the absorption of moisture by a spongy mass, like that in question, always to be neglected.

BESIDES these substances, many more are undoubtedly changed by the action of vital air, especially those containing phlogiston; but the mode is unknown.

XLVII.

Column Thirty-sixth, Phlogiston.

THIS very subtile matter admits, like the aerial acid, of two states, a state of combination, and freedom. In the former, it enters into the structure of bodies, eludes all our senses, and can only be recognised by its effects, for which reason some have supposed it to be a fictitious substance, and totally impalpable, but without just reason. The two celebrated philosophers, Priestley and Kirwan, have clearly proved its existence, both analytically and synthetically, so that I think all reasons for doubting are now removed. This principle, when in combination, and then it is properly called phlogiston, may be set loose by various methods; having recovered its elasticity, and
gained

gained an aerial form, by a proper increase of specific heat, it receives the name of inflammable air. In the next paragraph, we shall find data from the analysis of charcoal for estimating the weight of phlogiston in inflammable air; a cubic decimal inch of inflammable air is equal in weight to $\frac{6}{1000}$ of an assay pound, and it contains as much phlogiston as two pounds of forged iron, *i. e.* $\frac{5}{1000}$ *; therefore $\frac{6}{1000} \div \frac{5}{1000} = \frac{6}{5}$ give the weight of specific fire necessary to the aerial form, of which more will be said in the next paragraph, (XLVIII. C. E.). I speak here only of the inflammable air of metals: that which organic bodies yield, appears to be less pure, and especially combined intimately with a portion of aerial acid.

PHLOGISTON is perhaps to be found in all bodies, though in many it is concealed by its exility. The attractions of

* Analysis Ferri, p. 24.

of the more remarkable combinations into which it enters can alone be examined here; a task which is incumbered by no trivial obstacles. *Magnesia nigra*, for instance, attracts it with such violence as to decompose acid of salt. It takes this principle from all the metals, but not without the aid of some acid; a circumstance to be carefully noted. Nor does it act with so great force, till it has obtained the quantity necessary to perfect saturation, but only till it has acquired that which is necessary to its solubility in acids. When this point has been once attained, the complement which effects complete reduction is attracted more feebly than by any other metallic calx. An attraction of this kind, stopping at a certain point, takes place in many other metals, though it has hitherto been little examined. Thus, calx of iron, and perhaps of the other ignoble metals, by exposure to heat, acquires phlogiston enough to become

come magnetic, but cannot acquire enough for reduction. In general, the reducing portion of phlogiston adheres much more weakly than the coagulating. These attractions are in some measure analogous to those which acid of tartar exerts upon salts containing vegetable alkali, (XXXVII.). When the doctrine of affinities is brought to perfection, I foresee that it will often be necessary to adduce the same substance in two or more different states. Here the black and white calx of manganese may be introduced separately; but the former does not act by its single power, for it requires to be assisted by an acid. That, therefore, which is placed in this column is the white.

A PLACE can scarce be allotted to vital air, as it has scarce any effect, unless it be assisted by a double affinity, or a great degree of heat. We have before
spoken

spoken of its action on nitrous acid. Either external heat, or surrounding moisture, is necessary to the complete decomposition of phosphorus.

CALCINED mercury is reduced by digestion in acid of salt; but the cause has not yet been sufficiently explored. As this acid, when dephlogisticated, attacks the metal itself, the calx can scarce dephlogisticate the acid. It remains, therefore, to be examined, whether dephlogisticated air is produced during digestion. According to Mr Scheele's hypothesis, the decomposition of heat is sufficient.

VOLATILE alkali is dephlogisticated by magnesia nigra; but the cause is complex, depending upon nitrous acid.

THEREFORE these phænomena are at present of no use in determining the elective attractions; but the following
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are more simple, and seem adapted to this end.

NITROUS acid decomposes sulphur, very slowly indeed without boiling; but it separates the principles of muriatic acid in a middle temperature.

DEPHLOGISTICATED marine acid does not act upon sulphur; but it gradually decomposes white arsenic, and immediately resolves phosphorus into a white smoke.

THOUGH the precipitation of metallic solutions by complete metals is really the consequence of a double attraction, yet a single attraction would be sufficient, could phlogiston be supplied in a proper state. The inflammable principle has a different attraction for different calces, and combines with them to saturation; after which, the metals fall down in a complete state,
and

and cannot be redissolved, unless the excess of phlogiston be removed. When any other metal whatever is put into a solution of gold, the gold is immediately precipitated, not on account of the inferior attraction of the acid, as it has hitherto been universally explained, but because phlogiston more readily unites with the calx of gold, than with the calx of the added metal. That this is the true cause, may be shewn both by the dry and humid way. With respect to the latter, a fine discovery, made by Mr Sage, throws great light on the question. He puts into a diluted solution of a metal a piece of phosphorus, which yields its phlogiston to the metallic calx, and in some cases completely reduces it. The calces of the noble metals, and of copper, thus recover their metallic state*. Though there is here no reciprocal exchange of principles, yet two powers

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* Rozier, *Journal de Physique*, 1781.

effect the decomposition. Water alone gradually extracts the acid part of phosphorus, but very slowly, and thus renders the combination of the metallic calx with phlogiston more easy. We have experiments yet more direct. A solution of acid of arsenic in water is made to acquire a reguline form, by passing a stream of inflammable air through it, as Mr Pelletier attests*. The same thing happens to some other metallic solutions. Metallic calces may be reduced by the flame of pure inflammable air; which also happens if they are immersed in this air in close vessels, and exposed to the focus of a burning glass, as Dr Priestley has found. The air is diminished in this operation; but the residuum retains its former nature, and is just as fit for contributing to reduction as before. Besides, it is well known, that some metallic calces may be reduced by.

* Journal de Physique, 1782.

by fusion, with the addition of iron or any other proper metal.

THE phænomena, therefore, which come under this head, when deduced from their real cause, totally invert the series of metallic calces laid down in former tables. Thus, gold rises from the last place to the first or second, and zinc is reduced to the lowest. This holds with respect to the rest, as appears in the table of attractions.

IT is certain that the arsenical acid attracts the inflammable principle with greater force than the phosphoric; for if phosphorus be put into arsenical acid, the surface soon grows black in consequence of reduction.

IN the dry way, I have placed the metallic calces according to the order just established. I have placed the acid of arsenic before the calx of silver; for

this acid exposed to the action of fire with silver, dissolves a portion of it, which cannot be done without dephlogistication. The dephlogisticating portion is sublimed in the form of white arsenic ; the other immediately dissolves the calx.

SUPPOSING the matter of heat to consist of phlogiston and vital air, the place of vital air is between the calx of mercury, which is reduced as well as the noble calces, and the ignoble calces. It cannot, however, be denied, but that these also are capable of decomposing part of the heat, though not so as to effect a complete reduction.

XLVIII.

Column Thirty-seventh, the Matter of Heat.

A.] The nature of fire exercised the genius of philosophers in the earliest times, nor has the diversity of opinion yet been reconciled. Nay, it has been made a question, *Whether the phænomena which are ascribed to fire are to be deduced from a peculiar matter?* Or, *Whether they depend only on the motion of the particles of bodies?* Now since all motion, which is excited on our globe, meets with resistance, and, therefore, when left to itself; is progressively diminished, as every day's experience testifies, it is not easy to conceive how the motion excited by the production of a spark, which must meet with continual retardation, should nevertheless sometimes acquire such augmentation as to be able to consume a house, nay, a

whole city. Here the effect far exceeds the cause. But in this age, almost all philosophers agree, that there is a peculiar matter of fire, which has gravity ; exerts an attractive power ; possesses other peculiar properties very palpable in various cases, and capable of being accurately determined. I therefore think it superfluous to dwell any longer upon the proof of this position. The nature of this matter is a point much more difficult to be determined, and affords a fine field for the exertion of the greatest abilities. I think there can be no doubt that it ought to be called the matter of heat rather than of fire. Fire is the action of heat when increased to a certain degree, and, therefore, soon passes away after the consumption of the fuel ; but the heat continues though it becomes rarefied, and is distributed among other bodies. There is always heat in fire ; but all heat is not sufficient for exciting

citing fire : a determinate accumulation is required in every case.

UNLESS, therefore, we should chuse to invert the usual mode of speaking, the denomination which I have placed at the head of the paragraph seems more suitable to the nature of the thing.

B.] The chief opinions now prevailing concerning the matter of heat may be referred to three systems.

First, Some consider light itself as elementary fire, which every where surrounds our planet, in an uncombined state, becoming lucid when in sufficient motion, and occasioning different temperatures by its unequal density, highly elastic, light, subtile, and penetrating. Notwithstanding its wonderful tenuity and mobility, it may be fixed in bodies, and enter into their

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composition

composition as a proximate principle; in which state it is denominated phlogiston. The great simplicity of this hypothesis recommends it; but it can scarce maintain its ground, since it has been shewn that uncombined phlogiston is nothing but inflammable air, (XLVII.). Light seems moreover to be inferior in tenuity to heat.

Secondly, Others argue, that elementary fire, which in a state of liberty occasions warmth, is not only different from phlogiston, but so opposite that one every where expels the other, at least in part. Air during phlogistication gives out much specific fire, which, when free, heats, calcines, causes ignition, &c. It is proved, that the very attenuated matter of heat is not equally distributed, and in proportion to the bulk of bodies, as Boerhaave affirmed, but that each body, by a peculiar attraction depending upon its nature, acquires

acquires a greater or less quantity. If the heat marked by the thermometer is increased or diminished in a place where there are several bodies of the same weight, it is distributed among them in proportion to their powers; and in like manner, in restoring the equilibrium which is disturbed by a diminution, they exonerate themselves in proportion to their powers. A body absorbs more heat in becoming liquid than it contains when solid; and there is need of a still greater portion to induce the state of vapour. Animals grow warm by respiration, &c. not to mention other phænomena which will be related below.

PART of the system concerning the increase of latent or combined heat, when a solid becomes liquid, or a liquid is converted into a fluid, owes its rise to the illustrious Black. It has since been cultivated with so much success,

cess, both in England and Sweden, that it now seems to rest on a sure foundation *. The function of respiration has been particularly illustrated by Priestley and Crawford.

THE *third* system is that of my sagacious friend Mr Scheele, who thinks that the matter of heat is not simple, but compounded of phlogiston and vital air, closely combined, and that light consists of the matter of heat, with an excess of phlogiston. His Treatise on Air and Fire will best shew how he arrived at these conclusions. This hypothesis is not without its difficulties, which I every where mention ; it however seems to agree better with experiment than any other, and therefore I have often adapted my explanations to it.

* See Crawford on Animal Heat, Magellan du Feu Elementaire, and Wilcke, in the Stockholm Transactions of 1773,—1781.

it. It is by no means necessary in this hypothesis, that the contraction of the bulk of the air should always be ascribed to the heat passing through the glass. There is no reason why it may not be absorbed on particular occasions.

C.] I acknowledge that the new doctrine concerning the distribution of heat is well established in many respects; but as it is connected with attractions, it will be proper to explain with greater accuracy in what light I view it.

LET the heat which we can measure by the thermometer be called *sensible*, and that which is so fixed by the attraction of bodies, that it cannot be indicated by the thermometer, *specific*. For the sake of comparison, the specific heat of water is expressed by unity,
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to which the specific heat of other bodies of equal weight, and the same sensible temperature, is referred and expressed in numbers *, which indicate the proportion, but not the quantities. Let us suppose two bodies, *A* and *B*, of the same weight, whose specific heats are as *a* to *b*; let the sensible heat in the vicinity of the bodies be increased by the quantity *m*, which is to be divided between *A* and *B*, the former will receive an increase $= \frac{a}{a+b}m$, and the latter $= \frac{b}{a+b}m$, so that $\frac{a}{a+b}m : \frac{b}{a+b}m :: a : b :: a + \frac{a}{a+b}m \quad b + \frac{b}{a+b}m$. This is also the case if *m* be supposed to be negative, or to denote a diminution, for in either case such a distribution will take

* See Mr Magellan, who has given this theory an elegant mathematical form. The method of determining the specific heats differs from that of Wilcke, but the events agree; a circumstance which not a little confirms the truth of the doctrine.

take place, that the proportions of fixed heat shall remain the same.

BUT the specific heats do not follow the proportions of specific gravity, nor of bulk, but, if I mistake not, the compound ratio of the peculiar attraction, and the surfaces. I do not mean the mere external surface, but the internal likewise: it is well known that there is no body perfectly solid, nay, gold itself, the heaviest of all substances hitherto known, is perforated with invisible pores to the amount of one-half of its bulk, as has been rationally conjectured by Newton. Hence we may form some judgment of the vacuities of other bodies, since they may be at least relatively determined by their specific gravity; but this assistance is of no use in the present case. Though every other figure affords a larger surface, yet let us assume spherical pores for the sake of simplicity, and the vacuity

cuity of any body reduced to a sphere of the diameter 10, the internal surface will be as the square, that is, as $10 \times 10 = 100$. Suppose now this vacant space to be divided into ten equal spherules, of which let the diameter, to avoid fractions, be expressed by m , and the internal will be as $10 m^2$. If it be divided into an hundred spherules, it will be as $100 n^2$, and so we may go on as long as we please. Thus the internal surfaces increase as the size of the pores decrease, and, in the same proportion, the specific heats, if I am not mistaken. As the pores amount always to more than half the bulk, and in most inorganic bodies altogether elude the sight, however assisted, by their minuteness, the external surface may be neglected as infinitely small, and this perhaps holds concerning the peculiar force of attraction. The internal structure of bodies may indeed be truly compared to a sponge, though
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the apertures cannot in general be perceived. Now heat penetrates into all the pores of bodies, and when fixed, furrounds the smallest atoms like an atmosphere, and adheres to them, deprived of its power of exciting warmth. The thickness of this stratum is increased or diminished according to circumstances. The following are a few instances which seem to confirm my conjecture, for the nature of the thing forbids us to expect a rigorous demonstration. The particles of water, in the state of congelation, touching each other at a greater number of points, cohere in consequence of their attraction. But if a sufficient quantity of heat penetrates into ice, the particles are gradually separated, regain their little atmosphere, and recover their mobility. In a stronger heat the mass is dilated by larger atmospheres surrounding the particles, and their tenuity cannot but be increased by them.

Lastly,

Lastly, in the boiling temperature, every particle is so much dilated, as to occupy a space 14,000 times greater, and supposing the form to be spherical, as is in some measure visible, acquires a surface about 600 times more extensive. By this expansion, the contact and the attraction depending on it increases exceedingly, so that a remarkable degree of cold is produced in the contiguous bodies, by the quantity of heat necessary to saturation being collected and fixed.

My opinion is also illustrated by the following facts. Let a thermometer, with a void space above the liquor, and with the top close, be suspended in the receiver of an air-pump; as soon as the air begins to be rarefied by the strokes of the piston, the liquor of the thermometer will sink, as was first observed by Dr Cullen. The descent is owing to the dilatation of the glass, in consequence

sequence of the removal of the external pressure, for if the point be broken before suspension, the level of the liquor will not be changed by the rarefaction of the air. A vacuum does not therefore of itself produce cold. But if the globe of the open thermometer be moistened, the liquor will descend on the rarefaction of the air. The cause is to be sought in the ambient air, for its particles being expanded afford a space wider, and better fitted for absorbing heat especially from the water on the ball, which repairs its loss from the glass, and is converted into vapour; the glass attracts heat from the mercury, which therefore contracts, till the equilibrium be gradually restored from the neighbouring bodies. We have then three places filled of the column, at the top of which stands the matter of heat; the first is occupied by air, the second by glass, and the third by the liquid metal. That vapours

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transfer

transfer heat to rarefied air, I conclude from their sudden condensation into drops. It is obvious, that evaporation is much forwarded, in this case, by the rarefaction of the air. The moisture is dissolved by the heat which flows out, and is, therefore, expanded into vapours that are visible, and productive of cold, as is well known. The air, however, can scarce deprive the glass of its heat, without the expansion of the water into vapour, for when rarefied, it acts very slowly on the dry globe of the thermometer; abundant moisture acts more efficaciously than when it is in small quantity; nay, in general, the more volatile is the liquor used, the lower does the mercury descend. Therefore vitriolic æther, highly rectified spirit of wine, caustic volatile alkali, water and essential oils, should, it would seem, be placed in the series after air.

I HAVE formerly shewn that heat is absorbed during the solution of salts which acquire a far more extensive surface, and that it is let loose again by sudden crystallization*. For the same reason, muriatic air eagerly attracts phlogiston, (XVI.), not to mention other proofs of efficacy heightened by an increase of surface. Beyond the sphere of contact there is scarce any attraction, and therefore the area is of more importance than the density. For if as much be fixed to a dense, but small, as to a rare but extensive surface, the elasticity of the matter to be fixed will be more or less restrained below the equilibrium prevailing in the contiguous bodies, but the attractive power can scarce sustain such compression.

EVERY body has a determinate specific heat, which, however, appears,
Q 2 from

* Opusc. vol. i.

from experiment, to vary with the state of the body. In the solid state it contains least, in the liquid more, and the fluid, in which there is the weakest cohesion, has the most specific fire. Within the limits of the state of solidity, no variation has as yet been observed, though without doubt the specific heat ought gradually to increase, in proportion to the approximation to liquidity, and *vice versa*. It can scarce be doubted that such variations are perceptible in the state of fluidity.

Does this stratum of specific heat, which involves the smallest particles of a body, in any way affect the weight of the whole? Without doubt this subtle matter has gravity, and when it is so fixed to the body by attraction, as not to act upon the thermometer, it ought to cause an increase of weight. In solids, indeed, it constitutes but an infinitely small augmentation, so that the
weight

weight cannot be observed without great difficulty ; but in fluids, in which it abounds more, and bears a greater proportion to the weight of the whole, it ought not to elude the accuracy of our instruments. Some experiments of Mr Lavoifier afford hopes that it may be actually determined *. That very accurate chemist burned sulphur and phosphorus inclosed in common air by means of mercury ; and when the apparatus was grown cold, he found that the acids, when freed from their combination, twice or thrice exceeded the burned materials in weight. Now whence comes this increase? Let the table at the end of this paragraph be consulted, and it will be found that the specific heat of sulphur, and concentrated vitriolic acid, is as 0, 183 : 0, 758, that is nearly as 1 : 4. But if we consider, that the specific heat of vitriolic acid increases along with the inherent water,

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and

* Mem. de l'Acad. de Paris, 1777.

and that our usual concentrations leave a considerable quantity of superfluous water, we shall be obliged to own that the specific heat of the vitriolic acid, deprived of all extraneous water, ought to be reduced to 3, and probably still lower. Now Mr Lavoisier affirms, that the increments of the acid residua exactly answer to the weight of the vital air lost during the operation; whence, he justly concludes, that this air has been absorbed by the acid. As the specific heat of phosphorus has not yet been determined, a like deduction cannot be made with respect to it. Meanwhile, these experiments, instituted with a very different view, seem not a little favourable to Mr Scheele's hypothesis. When the vitriolic acid is set at liberty by the combustion of sulphur, its specific heat ought to be increased in the proportion of 3 : 1. This increase is found upon experiment to have taken place. At the same time,

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an equal weight of vital air is lost, and is quickly absorbed, together with that portion of phlogiston, which, when combustion is otherwise performed, generates vitriolic air; for the acid in Mr Lavoisier's experiments, was without smell. The like phænomena occur in the combustion of pyrophorus, as the same chemist has found. Does not then the matter of heat coincide with the combination of vital air and phlogiston in the present case? It has not yet been proved, nor is it indeed probable, that the aerial acid is among the principles of the vitriolic; it does not emit pure air, when combined with pure alkalis, unless perhaps in consequence of the decomposition of heat, but a large quantity of uncombined heat is extricated. Moreover, I think this experiment should be repeated, not only in mercury but in dry air, in order to try whether the vitriolic acid can be obtained dry. It is as yet doubtful, whe-

ther the liquid which we find, does not originate in part from extraneous moisture. A very accurate weighing of the residuum likewise, without any foreign additaments, may perhaps serve to determine the absolute weight of heat, which promises the illustration of many obscurities. Lastly, we see the preposterous manner in which the gravity of heat has been hitherto sought; metals, the heaviest of all bodies, have been used for this purpose, though they were of all others the most unfit.

THE last ten years are remarkable, among other things, for the change of many substances into an aerial form. And it is certain, that the generation of elastic fluids is highly worthy of examination. The experiments which have been hitherto made, seem to indicate,

I. THAT

I. THAT the *substances liable to this change are the more simple*, especially salts, both alkaline and acid. We have long known, that the vitriolic, nitrous, muriatic, fluor, and acetous acids, as well as all those of vegetable and animal origin, as also the vegetable and volatile alkali, may be brought to the state of air. These, retaining their acid or alkaline nature, are readily absorbed by water, and ought, therefore, to be collected in vessels full of mercury. The aerial acid is as yet of obscure origin. Moreover, sulphur* may be resolved into hepatic air; nay, siliceous earth, with all its fixity, may be made to assume the form of air †. Many more bodies will, doubtless, hereafter, be brought to the same state. Gold itself may be converted into the form of vapour by means of fire; but whether

* Opusc. vol. ii. pp. 340. 345.

† Ibid. vol. iii. p. 397.

whether it can put on that of air, cannot be determined *a priori*.

2. THAT *the principal cause of this transformation is to be sought in the matter of heat*, which subtilizes substances, and gives them elasticity, by loosening their particles. No elastic fluid is found without a large portion of specific heat; nay, phlogiston itself is resolvable by these means into an elastic form. The matter of heat comes in some processes, either from the fire itself, when, for instance, the aerial acid is expelled from chalk, inflammable air from iron by heat alone; or when it is extricated by the vitriolic acid, for in the new combination the acid cannot retain all its specific heat; what is superfluous is extricated, and either totally or in part absorbed by the air that is generated. This will be well illustrated, if we take equal portions of water, and add to the first, caustic vegetable alkali, to the second,

cond, aerated vegetable alkali, and to the third an equal weight of aerated volatile alkali; upon pouring in nitrous acid, a great degree of warmth will arise in the first, a moderate degree in the second, and in the third one still less considerable; nay cold, when the quantities are varied, is produced upon some occasions. The reason is, because, in the first case, the acid in uniting with the caustic alkali gives out its superfluous heat without diminution; in the second, the aerial acid absorbs great part of it; and as, in the third case, more of this acid is extricated, more heat is absorbed, inasmuch that the quantity set free being insufficient, the deficiency is supplied from the water of the solution, and sensible cold is generated. On the other hand, in the combination of the aerial acid with caustic alkali, the heat necessary to maintain the aerial form is set loose, and produces a degree of warmth corresponding

responding to its quantity. The other elastic fluids shew the same thing ; the contiguous bodies are cooled during their production, and heated when they are fixed.

3. PHLOGISTON appears *likewise to be necessary*. Thus the acids, as the vitriolic and the nitrous, which in a state of purity contain no phlogiston, are resolved by warmth into elastic vapours, but are condensed into drops on mere cooling ; but, by the addition of phlogiston, afford permanently elastic fluids : this substance is therefore to be considered as a bond, affixing the necessary quantity of heat. The same thing holds with respect to hepatic air, which cannot be obtained from sulphur, without the addition of phlogiston. But the acids which always contain phlogiston, as the muriatic, that of fluor, those procured from the vegetable and animal kingdom,

kingdom, need nothing but heat to put on an aerial form.

4. MOREOVER, *the different quantity of phlogiston occasions a great change.* In nitrous air extricated from different metals, there is some variation ; that which furrounds iron filings in a close vessel, is by degrees so much corrected that it not only does not extinguish flame, but even dilates it.

IN this state, it is called by some *de-phlogisticated*, with what propriety I can scarce perceive, since the filings are at the same time calcined, which clearly shews a loss of phlogiston. Besides, this experiment seems to coincide with that hypothesis which derives vital air from nitrous acid sufficiently phlogisticated. The electric spark taken in alkaline air, produces inflammable air, either by transmuting part of it, or, as it seems, by setting free the combined
phlogiston,

phlogiston, and furnishing the necessary specific heat; for the bulk is much augmented. Other instances of variation arise from the diminution of phlogiston: such is that elastic fluid which is called *dephlogisticated sea salt*. To this head we may also refer that air which is procured from nitrated volatile alkali, digested with magnesia nigra, and which resembles corrupted air. The power of magnesia nigra in dephlogisticating other substances is well known. That which is generated by the explosion of fulminating gold, in which some degree of dephlogistication certainly takes place, is of the same nature*.

ALTHOUGH the quantity of phlogiston in various bodies should decrease, as the specific fire increases, I would be far from deducing from this circumstance any mutual repulsion. The augmentations and diminutions compared together do not warrant such a conclusion;

* Opusc. vol. ii. pp. 161, 162.

sion; and spirit of wine, a substance abounding in phlogiston, has a greater quantity of specific heat than water, not to mention other arguments.

BEFORE I leave the genealogy of aeriform fluids, I must explain what I mean by the phrase *aerial form*. I understand by this term such a subtilization of a body as renders it elastic, pellucid, invifible, light and permanent in cold, though not capable of passing through the pores of glafs. *Vapours* which constitute imperfect kinds of air, are condensed by refrigeration. On the other hand, we have elastic fluids, which may be not improperly styled *æthereal*; to fuch, neither the pores of glafs, nor of any other known body, are impenetrable. To these belong the matter of heat, and the magnetic fluid. The electrical fluid easily penetrates all bodies, except electrics *per se*. Moreover, light seems to be something intermediate

mediate between aerial and æthereal substances ; for it passes through the pores of glass, but not those of metals and other opaque substances.

HENCE the necessity of determining the weight of the specific heat, in the analysis of aeriform fluids, plainly appears. With respect to inflammable air, I have before offered a sketch ; and I trust that Mr Kirwan, who has so successfully engaged in this task, will not neglect this important part, since the analysis will be otherwise imperfect ; and when it is once known, their nature and origin will be wonderfully illustrated.

HERE follows a table of specific, as far as they have been hitherto investigated. I thought it proper to dispose them according to the three states of solidity, liquidity, and fluidity. The specific heat of water is denoted by
unity.

unity. Water heated to 130 degrees melts an equal weight of snow ; but the water thus brought to a liquid state is at the point of congelation. It would certainly be worth while to weigh, with the utmost exactness, a piece of ice in a perfectly close vessel, and to repeat the operation after it was melted. The stopple must fit, in the most accurate manner, lest any thing should be lost in consequence of evaporation. This experiment has not yet, as far as I know, been performed with proper care and accuracy ; it may, however, ascertain, in some measure, the absolute weight of a quantity of the principle of heat corresponding to 130 degrees.

R

SOLIDS.

S O L I D S.

			<i>Spec. grav.</i>	<i>Spec. heat.</i>
Aerated volatile alkali,				1,851
Swedish glass,	-		2,386	0,187
Flint glass,	-	-		0,174
Agate,	-	-	2,648	0,195
Ice,	-	-		0,900
Sulphur,	-	-		0,183
Gold,	-	-	19,040	0,050
Silver,	-	-	10,001	0,082
Mercury,	-	-	13,300	0,033
Lead,	-	-	11,456	0,042
Copper,	-	-	8,784	0,114
Iron,	-	-	7,876	0,126
Tin,	-	-	7,380	0,060
Bismuth,	-	-	9,861	0,043
Antimony,	-	-	6,107	0,063
Brass,	-	-	8,356	0,116
Calcined lead,		-		0,068
Calcined iron,		-		0,320
Calcined tin,		-		0,096
A mixture of lead and tin calcined,		-		0,102

Diaphoretic

Spec. grav. Spec. heat.

Diaphoretic antimony		
washed,	-	0,220

L I Q U I D S.

Spec. grav. Spec. heat.

Pure water,	-	-	1,000	1,000
Clear vitriolic acid,			1,885	0,758
Dark coloured vitriolic acid,	-	-	1,872	0,429
Pale nitrous acid,		-		0,844
Red and smoking,			1,355	0,576
Smoking muriatic acid,			1,122	0,680
Red wine vinegar,		-		0,387
Concentrated distilled vinegar,	-	-		0,103
Alkali of tartar by deliquescence,		-	1,346	0,759
Caustic volatile alkali,			0,997	0,708
Of vitriolated fossil alkali				
1 part, in				
of water p. 2. 9:		-		0,728
	R 2			Of

Spec. grav. Spec. heat.

Of nitrated vegetable al-		
kali, p. 8.	- -	0,646
Of muriated fossil alkali,		
p. 8.	- -	0,832
Of muriated volatile al-		
kali, p. 1. 5.	-	0,798
Of depurated tartar,		
p. 237. 3.	- -	0,765
Of vitriolated magnesia,		
p. 2.	- -	0,844
Of vitriolated clay,		
p. 4. 45.	- -	0,649
Of vitriolated iron, p. 2. 5.		0,734
Brown sugar dissolved,		1,086
Oil of olives,	- -	0,710
—— linseed,	-	0,528
—— whale, (spermaceti)		0,399
—— turpentine,	-	0,472
Rectified spirit of wine,	0,783	1,086
Volatile liver of sulphur,	0,818	0,994

FLUIDS.

F L U I D S.

		<i>Spec. grav.</i>	<i>Spec. heat.</i>
Vital air,	-	000,132	87,000
Atmospheric,	-	000,125	18,000
Aerial acid,	-	000,181	0,270

I HAVE been informed by Mr Kirwan, in a letter, that Dr Crawford found the specific heat in equal bulks of inflammable and atmospheric air equal. Admitting this, if the species of air in Mr Kirwan's table, published by Mr Magellan, are estimated by weight, the specific heat of inflammable air will be 281, which is more than triple of that of vital air.

D.] The theory of the distribution being now in some measure explained, it is proper to consider the origin of

R 3 fire

fire in *inorganic* bodies, its propagation, and the consequences.

FIRE is such an accumulation of heat that the bodies exposed to it become ignited or inflamed. The chief means of exciting it are :

1. THE striking of flint or pyrites against steel, by which the abraded globules are ignited, fused and calcined.

2. THE forging of iron, which is brought to ignition by repeated strokes of the hammer.

3. THE mixing of sulphur and steel filings, which, with a proper degree of moisture, grow warm, and burst afterwards into flame.

4. ADDING the smoking nitrous acid in a proper manner to oils.

5. PYROPHORUS grows red hot in atmospheric air, and produces flame in vital air *.

IN all these cases, there is no heat produced without vital air, which also, according to circumstances, is more or less diminished. Phlogiston is likewise present in them all. The late English philosophers contend, that the disengaged phlogiston unites with vital air, and forms aerial acid, or when in a larger proportion corrupted air, by which change, a great quantity of specific heat is necessarily set loose, and being accumulated, produces ignition, and even flame when inflammable air is present. Scheele contends, that vital air may be totally changed by phlogiston into the matter of heat. Both

R 4

opinions

* Mr Kirwan has lately informed me by letter that there is a certain kind of earth found in Derbyshire which takes fire in a short time, on the addition of linseed oil. I have not as yet seen this earth.

opinions are supported by strong arguments. It is, therefore, of great importance, that the nature of the combination of phlogiston and vital air should be demonstrated. Mr Kirwan thinks the aerial acid is the product; and by his sagacity, has been able to render this opinion very probable: there is, however, still room for some doubts; when these have been removed, the system of Scheele will scarce be tenable. It is probable, that, in the two first cases, a part of the specific heat is expressed by the compression of the pores, and accumulated when the dephlogisticating temperature commences, and is afterwards increased by the surrounding air. The ignition or inflammation of inorganic bodies is propagated to others that are capable of it, by contact or vicinity. All bodies may be ignited; a few only can be inflamed; such are sulphur, phosphorus,
inflammable

inflammable air, arsenic, zinc, and some others.

THE consequences of ignition or deflagration vary according to the diversity of bodies, and the degrees of fire. The accumulation of heat causes expansion, dries, liquefies, makes bodies red hot, expels such as are volatile, indurates, inflames, volatilizes, calcines, vitrifies, reduces. The residua absorb a quantity of heat suitable to their nature, as is very evident from pyrophorus, which destroys, during its ignition, nearly $\frac{3}{4}$ of atmospheric air, whereas other mediums scarce diminish it by $\frac{1}{5}$: in vital air it takes flame, and nearly $\frac{1}{4} \frac{4}{4} \frac{3}{4}$ disappear*. The cause is to be sought in the hepar which is contained in pyrophorus, and in the decomposition of the sulphur, in consequence of which the vitriolic acid is laid bare, and must necessarily be furnished with its portion

* Lavoisier, l. c.

portion of specific heat *. Some residua are of an acid nature and deliquescent. Others are found in the form of calces, ashes, saline or resinous compounds.

E.] *Vegetables*, though they yield the greatest quantity of combustible matter in our globe, and easily propagate fire once lighted, generate it themselves but very slowly. To produce it by friction, there is required wood, hard, dry, and penetrated with much inflammable matter, and even, in these circumstances, the operation is a trial of patience. It is said, that fire has often arisen from the accumulation of grass not sufficiently dried, but no one yet, as far as I know, has examined these phenomena with due care.

WHEN dry wood is exposed to fire, it grows warm and expands; the humidity, which is generally acid, is resolved
into

* See the subdivision marked C.

into vapour ; the phlogiston is disposed to be driven off, and then is attracted, partly by the surrounding vital air, and is partly disengaged with the requisite specific heat in the form of inflammable air, and, in the same instant, is set on fire and produces flame. Thus, the whole fabric of the wood is gradually destroyed, and, in the mean time, more or less smoke is emitted, by which the soot is deposited. Fire cannot subsist without vital air. Hence, when it is lighted, an afflux of air in a continual stream takes place, which rises loaded with phlogiston, and rarefied by warmth, carrying along with it carbonaceous particles not sufficiently burned ; which particles are loaded with fixed vegetable as well as volatile alkali, and with earth and sal ammoniac. I have asserted, that the particles not sufficiently burned, generate soot ; for the furnace, which has the name of

απόπνυξ

ἀνάπνοος, totally destroys the smoke which is brought through the fire-place.

WHEN the inflammable air, and, of course, the flame fail, the conflagration is diminished, and nothing but charcoal and ashes remain. In a close vessel the charcoal amounts to one-fourth, seldom to one-fifth of the weight of the wood ; but in the open air, great part of the charcoal is resolved into ashes. This is effected by a double attraction ; the vital air solicits the phlogiston, while the alkali and alkaline earth attract the aerial acid. In a close vessel charcoal resists the most intense fire. This substance is nothing but a combination of phlogiston and aerial acid, a species of sulphur which is found intimately combined with caustic alkali and alkaline earth, and hence it approaches, in some measure, to the nature of hepar. By combustion in the open air, 100 parts of charcoal contain

contain about 6 of ashes ; of these $\frac{1}{9\frac{1}{10}}$ consists of alkali, the rest of earth, in great measure alkaline. I have particularly examined well burned charcoal made of the *pinus sylvestris* of Linnæus. Of this 1 part, during detonation, alkalizes 3 of nitre, hence the phlogiston it contains, is, in comparison of that contained in forged iron, as 3 to $\frac{1}{2}$ *. Upon 100 parts reduced to powder, I poured concentrated vitriolic acid, then distilled to dryness, and, in a pneumatic apparatus, collected about 82 cubic inches of aerial acid, of which each is equal in weight to a docimaftic pound. If then we add 3, which nearly correspond to 6, the parts of the aerated ashes, there remain 15, which give the weight of phlogiston. No vestiges of vital air appear. The proportion of the principles varies according to the diversity of the wood, age, exsiccation, and

* *Analysis ferri*, pp. 51, 52.

and combustion. Meanwhile; it appears from preceding observations, that 1 part of phlogiston can fix nearly $5\frac{1}{2}$ of aerial acid. The specific heat of wood is a little greater than the specific heat of charcoal, of equal weight.

MOREOVER charcoal has a peculiar attraction for elastic fluids. Ignited charcoal absorbs, during refrigeration, about 6 times its own bulk of any kind of air. If the hot coal be cooled in quicksilver, or in a void space, it nevertheless retains this power of absorption, and, when immersed in air, exerts it instantaneously, as the celebrated Fontana has observed. This air is expelled by water or any other liquid.

THE parts of animals are, in like manner, consumed and converted into charcoal, which, however, seems to abound more in phlogiston, and to retain it more obstinately. I have not yet

yet attempted to analyse it. Soot from animal substances generally abounds more in volatile alkali and sal ammoniac, than that obtained from vegetables. The smell of the smoke is exceedingly offensive.

F.] In animals with hot blood, we find a sensible temperature superior to that of the atmosphere, which is also constant and permanent, though the surrounding medium, from its greater coolness, ought to absorb the difference, as happens in the case of other bodies. This phenomenon indicates a cause perpetually in action, which, in this age, has been sought by many, but seems to have been most successively investigated by Dr Crawford. Many considerations tend to shew, that animal heat is generated in the lungs. The larger these are, the hotter are the animals. Hence birds exceed animals in this respect. Respiration is accelerated by

a more violent motion than usual, and the heat is at the same time increased, an effect to be ascribed to the quantity of air respired, and by no means to friction in a body full of liquids. Animals without lungs have their temperature depending on that of the medium in which they live; to us they feel cold, not to adduce any more proofs of the efficacy of the air. But the manner in which the effect is produced, is connected with the present enquiry. Dr Priestley contends that common air serves to carry off the superfluous phlogiston of the body. Dr Crawford afterwards embraced this opinion, and has admirably illustrated the whole process. Having not yet seen his pamphlet, I have borrowed my idea of his system from Mr Magellan's essay. The specific heat of common air is to that of aerial acid, as 69:1, so that if these two fluids were to receive an addition of heat of one degree

gree

gree, the former would fix 69 times more than the latter. Now we know, from the observations made at Peterburgh, that the mercury may descend at least 111 degrees of the Swedish thermometer, below the mean temperature. Therefore, if the common air was to be changed into aerial acid, $69 \times 111 = 7659$ degrees of heat must be set free, *i. e.* 13 times more than is necessary to turn iron red hot. Now, as common air is phlogisticated in the lungs, and converted into aerial acid, we may hence form some judgment of the quantity of heat, which is set free by respiration, and may serve to warm the body. Besides, as the specific heat of the arterial blood is to that of the venous, as 100 : 89, the author thinks it evident, that phlogiston is gradually accumulated in the veins, and exonerated in the lungs,

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that

that the blood may be rendered capable of receiving the due specific heat.

ALL this is pretty consistent, and highly ingenious: but that all the fundamental parts of this theory, which are certainly not improbable, may be further illustrated by new experiments, I shall add a few remarks.

I. IT remains to be ascertained, whether animals or vegetables contain most phlogiston. I know no experiment which decides this question, and it seems indeed very difficult of solution, for the problem is, not concerning this or that particular part, but to compare the whole body of an animal with a vegetable of the same weight. If we consider our food, consisting entirely of organised bodies, we shall find that they have been for some time dead, before they appear on our tables, often long before; and there can be no doubt,

doubt, but more or less of phlogiston is extricated during the interval. Next the operations of cookery dissipate a considerable quantity, nor can we be certain that this is compensated by the fauces. The flatulency that is expelled from the belly, is inflammable, and the solid excretions are well known to abound with phlogiston. Besides, a great quantity of phlogiston seems to be requisite for the purposes of the animal œconomy at all times, and in every part of the system, and I confess that I know not whether that which is taken in with the ingesta is sufficient. Still less can I be certain that there is any superfluity to be carried off.

2. EXPERIMENT shews a greater specific heat in the arterial than the venous blood. Let us grant that the accession of phlogiston often lessens the specific fire, it by no means follows that

S 2

phlogiston

phlogiston is the agent in the present case. We have other means of bringing about the same diminution. Thus the purest vitriolic acid, added to water, excites a great heat. The water combined with the acid cannot retain all its former specific heat, wherefore the superfluous part is set free, and that without the aid of phlogiston. While the blood is circulating, various changes may diminish the specific heat, which indeed seems necessary, that the parts at a distance from the heart, may continually receive some heat.

3. I KNOW no experiment which directly shews that the blood imparts phlogiston to the air. The air is indeed corrupted, but that this can only be effected by phlogiston, is a mere supposition. On the contrary, by the contact of blood, nitrous air is dephlogisticated,

dephlogisticated, and atmospheric air is meliorated *.

4. THAT the expired air contains a portion of aerial acid cannot be doubted, but I think that the quantity requires to be determined more accurately. If all that is good is converted into this acid, 1000 cubic inches of atmospheric air, of which one $\frac{1}{3}$ is vital, ought, according to the analysis of Mr Kirwan, to be condensed to the bulk of about 926, *i. e.* $\frac{1}{14}$ should disappear, and of vital air, 1000 should be reduced by respiration to 863, *i. e.* they should be diminished by $\frac{1}{3}$, if they can be inhaled by the lungs till they are totally corrupted. Supposing that aerial acid is further changed into corrupted air, a smaller contraction may be expected.

BUT the doctrine concerning the origin of animal heat, is reducible to the
S 3
fundamental

* Dr Priestley.

fundamental question, concerning the change of vital air into aerial acid, and of this into corrupted air; an opinion which every day seems to receive confirmation. Mr Kirwan has lately communicated to me a new experiment of great importance, made by Dr Priestley: That calx of mercury, which is commonly called precipitate *per se*, and which, when exposed to fire, yields pure vital air, afforded but $\frac{1}{8}$ of vital air on the addition of iron filings, and $\frac{5}{8}$ of aerial acid. If the filings had suffered no degree of calcination, this result seems to decide the question. Meanwhile, I rejoice, that it is reduced to such a state, that we cannot long remain uncertain.

XLIX.

Column Thirty-eighth, Sulphur.

SULPHUR prefers fixed alkalis to earths ; on which account, hepar made with lime, and dissolved in water, is decomposed by alkali, and a saline hepar is formed. Between vegetable and mineral alkali no difference in this respect has yet been observed. The power likewise of ponderous earth has not been ascertained ; it probably yields to fixed alkali, for volatile alkali, both caustic and aerated, precipitates hepar made with lime, when dissolved in a small quantity of water, and separates the calcareous earth. Let magnesia alba be put into a phial with flowers of sulphur, and distilled water ; let the phial be closely stopped, and then digested a few hours in a water bath ; when it is afterwards cooled, it will yield a

weak solution, emitting an hepatic smell, and turning black on the addition of nitrated silver, or acetated lead.

VOLATILE hepar, obtained from sulphur distilled with sal ammoniac and lime, is very soon decomposed in the open air, since pure volatile alkali attracts the aerial acid in preference to sulphur. That this alkali is superior to earths, appears from what has been said above. It is well known, that mercury and arsenic take sulphur from it, for these metals, and even their calces, when added to the volatile hepar, are mineralized in the moist way; the former yielding cinnabar, and the latter red arsenic. It is probable, that this is true of other calcined metals. Hence it appears, that the calces of metals may be combined with sulphur, a truth which ochre of iron shews clearly and directly; for by being mixed with sulphur, it yields efflorescent vitriol: the
operation

operation may be forwarded by moistening the mixture. It has been elsewhere shewn*, that calx of antimony can take up sulphur. Nay, the calces of lead, tin, and silver, when added to saline hepar, seem to take sulphur from vegetable alkali.

It now seems no longer doubtful, where the oils should stand in columns 26 and 27; for I have observed, that a drop of oil, added to either saline or earthy hepar, produces white coagula, resembling soap. This matter is also soluble in spirit of wine, and the oil may be precipitated from such a solution by water. But it is as yet undetermined in what order sulphur attracts the oils.

In the dry way, alkali occupies the first place; then follow the metals, of which the respective station is to be ascertained

* De antim. sulphur. p. 177.

ascertained by their mutual precipitations ; but as distinct reguli are seldom obtained by these means, the operation ought to be frequently repeated, that the truth may be fully determined : the places of nickle and of cobalt are as yet uncertain. Gold, platina, zinc, and perhaps manganese, refuse to unite with sulphur, unless they be conjoined with some proper additament.

L.

Column Thirty-ninth, Saline Hepar.

SALINE liver of sulphur has no place here, except in those cases in which it suffers no decomposition. It dissolves and retains almost all the metals, zinc alone excepted ; but no one has ascertained with what force it attracts them, and whether they can be mutually precipitated in the dry way. They
can

can seldom be combined without fusion ; but when the combination is once formed, it is soluble in water. Mercury, however, and antimony, are dissolved in the moist way, with the assistance of heat, which has not yet been ascertained with respect to any other.

HEPAR dissolves charcoal both in the dry and moist way ; the solution is of a green colour.

IN the dry way, the metals precipitate one another more distinctly than when combined with sulphur ; the operations should be repeated oftener than once, that we may be quite certain of the conclusions ; and though I have several times made such experiments, I have not yet attained so much certainty as I could have wished. Meanwhile, I follow the order which my experiments have suggested ; I leave it to
be

be confirmed or corrected by future trials.

MANGANESE seems to have the same attractive force as iron ; at least I have not yet been able to separate them by means of hepar. Next follow, iron, copper, tin, lead, silver, gold, antimony, cobalt, nickle, bismuth, mercury, and arsenic. The places of the two last particularly are doubtful ; nor are those of gold and antimony satisfactorily settled.

LI.

Column Fortieth, Spirit of Wine.

I HERE suppose the spirit deprived, as much as possible, of superfluous water ; that I mean which does not enter into its composition. It attracts water very forcibly,

forcibly, infomuch that æther diffolved in it is feparated, at leaft in great meafure. Effential oils feem to adhere to it with lefs force than æther. It takes up pure alkalis, and hepar, but the order is as yet unfettled. The Count de Lauraguais has fhewn how the vapours of fulphur may be diffolved in fpirit of wine.

LII.

Column Forty-first, Æther.

THIS, as it were, intermediate fubftance between fpirit of wine and effential oils, forcibly attracts fpirit of wine, effential and unctuous oils. I cannot yet eftablifh with certainty the fuperior force of either of the firft mentioned fubftances. Such is its fubtilty, that it diffolves the elastic refin, which, as
well

well as sulphur, may be precipitated by water.

LIII.

Column Forty-second, Essential Oil.

THESE oils take up æther, spirit of wine, and sulphur, but the series has not been sufficiently examined; nor can this easily be done, since they do not precipitate each other, but form triple compounds.

LIV.

Column Forty-third, Unctuous Oil.

FIVE substances occur here, but their places, if we except the last, are not clearly fixed. Some acids take up empyreumatic vegetable oils. Spirit of
tartar,

tartar, as it is called, absorbs no small portion of oil of tartar ; and therefore, at the conclusion of the distillation, they should be separated, otherwise the oil will be sensibly diminished by the acid. Vinegar has likewise this power.

LV.

Column Forty-fourth, Gold.

I HAVE already several times noticed the difference between the noble and ignoble metals. The king of metals, to speak with the ancients, is directly attacked by dephlogisticated muriatic acid, (XVII.) by aqua regia, (XVIII.) and nitrous acid, (XIV.) ; but the other acids, being deficient in power to carry off the necessary quantity of phlogiston, do not take it up, unless it has been precipitated from some one of the three just mentioned. That a precipitate
procured

procured by alkali is a true calx of gold, is evident from the want of brilliancy, its solubility in aqua regia without producing red fumes, its power of tinging glafs, &c. The calx is dissolved by the acids of vitriol, arsenic, fluor, tartar, phosphorus, fat, and above all, by the acid of sea-salt in its entire state; but the series remains to be ascertained. The acid of ants has not this power, at least it does not turn yellow; the calx, however, soon grows black, but is not reduced, since it is taken up by muriatic acid. The same thing is true of vinegar; but instead of a black colour, an obscure purple is produced. The acid of Prussian blue, saturated with calcareous earth, precipitates gold from aqua regia, in the form of white powder; but when too much is added, it dissolves the sediment. The powder of gold precipitated by alkali, in like manner grows white, when

when put into the acid of Prussian blue.

ÆTHER takes gold from all the acids. It also directly dissolves the calx, leaving gold itself, however minutely divided, quite untouched.

CALCINED gold seems moreover to be soluble in alkali; for when it is added to a solution of gold, so as to exceed the point of saturation, there still remains in the solution enough of the metal to produce a distinct yellow colour.

IN the dry way, gold combines with all the metals; but in what order they are to be placed, can scarce be discovered, since three and more easily unite without the exclusion of any one, (VIII.). I have, however, placed those uppermost to which it seems most willingly, and those below to which it seems more re-

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luctantly

luctantly to unite. The same thing holds with respect to most other metals, concerning which let this admonition suffice.

GOLD is soluble in saline hepar, though it rejects sulphur.

LVI.

Column Forty-fifth, Platina.

WHAT has been just said of gold, is applicable in great measure to platina, which, however, in the state of a precipitate, is soluble in more acids, as in that of sugar, sorrel, lemon, ants, and in vinegar. The acid of Prussian blue seems to have no power either as a precipitant or a solvent.

THAT platina is always contaminated with iron, in my opinion, indicates
nothing

nothing but the presence of both metals in the places where platina is found: He also who shall consider the great difficulty with which platina is fused, will not wonder that the alloy is defended by it so as scarce to be separable. This is strongly confirmed by the precipitate of platina from aqua regia by sal ammoniac, which shews no vestiges of iron, when it is well fused in microcosmic salt *. It seems most probable that the magnetic power of the inherent iron is acquired by the triture in the iron mould, while the gold is amalgamated; it is at least by this means contaminated with quicksilver. Scarce any platina is brought to Europe, which has not first undergone this operation. Gold mixed with iron in such a proportion as to equal platina in specific gravity, totally differs from it.

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* Opusc. vol. ii. p. 179.—181.

THE experiments of the celebrated Dr Lewis seem to indicate that platina is in some degree attacked by liver of sulphur.

LVII.

Column Forty-sixth, Silver.

MURIATIC acid attracts silver more strongly than any other, and takes it from all the rest. The acid of fat, however, seems to equal it. It is probable that the acid of Prussian blue is superior to none but the aerial. By the former saturated with lime, silver is precipitated from vitriolic and nitrous acid, in the form of a white powder, but is redissolved when too much is added. The acid of sugar seems to come next that of fat, for it decomposes lunar vitriol by attracting its metallic basis: nitrated silver is precipitated by the
vitriolic

vitriolic acid, by that of sugar of milk, and likewise by the arsenical acid, but so imperfectly that it should, in appearance, be placed after that of nitre. The places of the following acids are less certainly determined. Silver precipitated by crystallized alkali is soluble in aerial acid, which may again be expelled by fire; aerated silver, however, is not taken up by water. Vitriolated silver is not precipitated by aerial acid, unless it contain a mixture of muriatic acid,

PURE volatile alkali dissolves calcined silver, and the solution will afford crystals. There is a new class of salts, consisting of metals dissolved in alkalis, highly worthy of attention, though they have as yet been but little, or not at all, examined.

LVIII.

Column Forty-seventh, Mercury.

MERCURY, in point of fusibility, constitutes one extreme among the metals, and platina the other. The former requires only such a degree of heat as is rarely wanting in our atmosphere, but when the cold is increased by art to the temperature denoted by 40° of the Swedish thermometer, this metal likewise begins to concrete, and, in due time, becomes quite hard. Dr Pallas says that it was several times congealed in Siberia by the natural cold. In its common state, therefore, it is to be considered as a metal in fusion; and since, in its solid state, it is nearly as malleable as lead, it by no means ought to be placed among the semimetals, otherwise the whole class must be considered

sidered as brittle, for none is malleable when in fusion.

Acid of fat is placed first, for it disengages all the rest, even the muriatic, to which the second place belongs. The acids of sugar, sorrel, amber, arsenic, and phosphorus, soon expel the vitriolic and nitrous, and fall with the calx of quicksilver to the bottom ; but their respective forces have not been sufficiently compared : acid of sugar of milk precipitates mercury, but yields to the muriatic, but whether to the vitriolic and those yet stronger, is uncertain. Acid of lemon produces a copious precipitation of mercury, dissolved in the cold in nitrous acid, though but a sparing one when the solution is forwarded by heat. The same holds with respect to the acid of tartar, of which it is moreover certain that it yields to the vitriolic. The fluor acid seems to be weaker than the nitrous : the acid

of ants does not, as we learn from Margraaf, dissolve, but reduce the calx. The stations of acetous acid, phlogistified vitriolic acid, and the acid of borax, remain to be ascertained with greater accuracy. The calx of mercury, precipitated by mild alkali, combines with the aerial acid; but this metallic salt is not soluble in water. The acid of Prussian blue decomposes aerated mercury, and forms crystals. This acid precipitates silver from its solution in nitrous acid, when made in the cold, in the form of a black powder. Whether it prevails over the vitriolic, and those still stronger, by its single power, has not yet been determined by experiment.

LIX.

Column Forty-eighth, Lead.

THE vitriolic acid attracts lead with greater force than any other, and immediately takes it from them. The acid of Prussian blue, alone, has no power; but by a double attraction a white powder is separated, which cannot be redissolved by adding an excess of the precipitant. The acids of fat, of sugar of milk, sugar, arsenic, tartar, phosphorus, and sorrel, certainly expel the muriatic and nitrous acids, at the same time forming new compounds scarce soluble; but their respective order requires to be ascertained by farther examination. The fluor acid prevails over vinegar, as also do probably the acids of lemon and ants. To the rest, the observations in LVIII. are applicable. The calx of lead, when it contains

tains no aerial acid, seems to attract it with the same force as fixed alkali, for the calx in this state renders the alkali caustic in part, as reciprocally happens to the aerated calx when put into the caustic ley.

PURE fixed alkali, and also unctuous oil, dissolve the calx of lead.

LX.

Column Forty-ninth, Copper.

ACID of sugar occupies the highest rectangle, since when it is dropped into vitriolated or muriated copper, it seizes the metal, and exhibits at the bottom of the vessel a greenish sky-blue powder. Acid of tartar likewise precipitates these salts, but not so quickly; it forms blue crystals. The muriatic acid is superior to the vitriolic, for blue
vitriol

vitriol is readily dissolved in it; the menstruum soon grows green, and yields a yellow sympathetic ink, which cannot be obtained without muriated copper; not however to trust to the colour alone, I add highly rectified spirit of wine to muriatic acid, saturated with vitriol; no separation, however, took place, as necessarily happens whenever copper is united with vitriolic acid. At the same time, let it be observed, that a very small degree of heat, even the rays of the sun, restore the superiority to vitriolic acid, insomuch, that crystals of vitriol are at last obtained, or may indeed be separated by spirit of wine without evaporation. This is a remarkable instance of the power of heat, (IV.). The muriatic acid dropped into a solution of nitrated copper, precipitates a white saline powder, consisting of marine acid and the calx of copper in excess: this powder is not soluble in water. The acid of fat, of sugar of milk, and
of

of nitre, are expelled by the vitriolic, and the acetous by the arsenical; but the strength of the rest has not been sufficiently examined. The Prussian acid, without assistance, decomposes aerated copper; but scarce any other compound of this metal. When combined with alkali, it decomposes them all, by means of a double attraction, and the precipitates are redissolved when too much is added. The other acids take up only part of these sediments; what remains is of a white colour. Volatile alkali totally dissolves them; the colour of the solution is a bluish green, but they are again precipitated by water.

ALKALIS and oils attack copper, but in what order is not known.

LXI.

Column Fiftieth, Iron.

Acid of fugar immediately turns a solution of martial vitriol yellow, and gradually separates a yellow powder, consisting of the calx of iron, and the added acid. The acid of tartar, in like manner, decomposes it; but the new salt does not so soon become visible, and it is more crystalline. Green vitriol, dissolved in muriatic acid, is separated by spirit of wine, and therefore the vitriolic is to be placed first. Acid of fugar of milk is incapable of separating the vitriolic acid; and the acid of fat yields to the nitrous. Prussian blue is dissolved by its own acid; the solution is of a yellow colour: other acids have no action upon it, which would seem to shew that this acid has
the

the strongest attraction for iron ; and it does indeed precipitate it from the aerial acid, but from no other, as far as I know, unless it is saturated with alkali, that is, by means of a double elective attraction. The following places remain to be confirmed by farther experiment ; it is, however, certain that the acetous acid is inferior to the arsenical.

LXII.

Column Fifty-first, Tin.

IN almost the whole of this column the series is doubtful, and very difficult to be ascertained, since tin requires an excess of acid to be suspended. It is certain that the acids of arsenic, and sugar of milk, yield to the vitriolic and marine, while they are superior to the acetous. The acid of
fat

fat exceeds the marine in strength of attraction.

BOTH fixed and volatile alkali attack calx of tin.

LXIII.

Column Fifty-second, Bismuth.

BISMUTH readily dissolves in nitrous acid ; but the acids of sugar, fat, forrel, tartar, phosphorus, and arsenic, when added to this compound, attract the basis ; but their relative powers are undetermined : the new compounds fall to the bottom scarce soluble, in the form of very fine powder, except only tartarized bismuth, which, however, affords pellucid crystalline grains, in 10—15 minutes. As water alone causes a precipitation, I either employed a solution with such an excess of acid, that

a number of drops of water, equal to that of the precipitants, caused no permanent cloudiness, or else added acids, which may be procured in a concrete form, as most of those just mentioned. These acids, in like manner, decompose a solution of bismuth in the vitriolic acid: which menstruum, when diluted, attacks the calx; but to dissolve the regulus, it must be in a concentrated state; and, in order to separate the phlogiston, it must be evaporated to dryness.

DISTILLED vinegar boiled with the calx of bismuth for half an hour, does, in reality, dissolve part, as appears from the taste, the addition of phlogisticated alkali, and the above mentioned acids; what is dissolved cannot be precipitated by water, unless perhaps in great quantity, and by long standing. The regulus is dissolved in the same manner, but so sparingly that it can scarce be ascertained. What has been said
concerning

concerning vinegar, is likewise applicable to acid of ants. The remaining places are uncertain, nor are even the respective powers of vitriolic, nitrous, and marine acid determined.

LXIV.

Column Fifty-third, Nickle.

NICKLE is not yet universally acknowledged as a distinct metal; but as it may be distinguished from others by constant criterions, such as its deep green colour, when dissolved in those acids which attack it; its blue colour in volatile alkali; the greenish white precipitate it yields on the addition, either of common or phlogisticated alkali; the hyacinthine tinge it communicates to glass, characteristics which, taken together, belong to no other; moreover, since when it is properly

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purified,

purified, it cannot be resolved into others, though it be ever so long tortured, both in the dry and moist way; lastly, since no one has produced by synthesis, a mixture agreeing with nickle in the properties above mentioned, from copper, arsenic, purified cobalt, iron, or other metals fused together; for these several reasons, I cannot but consider nickle as a distinct metal, till I am better informed by new experiments. Most chemists have been seduced by the extreme difficulty which attends the purification of it. It is indeed always contaminated with arsenic, cobalt and iron, sometimes also with copper and other metals. Copper is easily separated, arsenic with great difficulty, the last vestiges of cobalt with still greater, but iron by no method hitherto discovered, as is related more at length in my dissertation on this metal. I do not, therefore, wonder

wonder that nickle, if it be so sparingly contaminated with cobalt, that the particles of the former metal surround those of the latter on every side, should not afford, according to the common method, glass of a green colour, and yet that this colour should appear on the addition of white arsenic; for this addition not only weakens the cohesion of the cobalt and nickle, but renders the mass more fluid, and deprives the cobalt of the phlogiston which before prevented the effect. Cobalt does not tinge glass, except when in the state of calx; this calx contains a wonderful store of colours; but when excessively dephlogisticated, it cannot either be fused or reduced, without great difficulty. Nickle contaminated with iron alone, which I have not been able to remove by any means, is malleable, and very tenacious, so that I doubt whether it ought to be reckoned among the brittle metals. It is sometimes magnetic, is

difficult of fusion, and does not yield a blue glass on the addition of white arsenic ; it, however, gives a very deep green to acid menstrua, and shews the above mentioned criterions.

NICKLE prefers no acid to that of sugar ; by this it is taken from every other, and appears in the form of a whitish green insoluble powder : It is likewise precipitated by acid of sorrel. The acid of fat yields to the nitrous. The other places remain to be determined by farther examination ; the trials, however, that have been made, seem to indicate that the arsenical acid is to be placed after the acetous.

LXV.

Column Fifty-fourth, Arsenic.

THE solutions of arsenic are, in some measure, imperfect, at which we need not be surpris'd, the calx being only a real acid, coagulated by phlogiston, (XX.). It has, however, as yet been little examined, with a view to its elective attractions. That the vitriolic acid yields to the muriatic, appears from this, that arsenic, dissolved in the former, yields, upon addition of the latter, and exposure to a very gentle heat, butter of arsenic. The vitriolic is likewise extruded by the saccharine, and the sebaceous by the nitrous. The rest is doubtful.

LXVI.

Column Fifty-fifth, Cobalt.

COBALT differs from nickle, in imparting a red colour to all the acids, and volatile alkali, when it is dissolved in them; in the reddish ash-coloured precipitate thrown down either by common or phlogisticated alkali; in attracting saline hepar from nickle in the dry way; in refusing to combine with silver, bismuth and lead by fusion, which metals do not reject nickle unless it contain too much cobalt; in the superior richness of its colour; for which reason, though it be present in the same mass, in far less quantity than nickle, yet it prevails; for a regulus containing a much larger portion of nickle, yields nevertheless a red solution in acids, without any shade of green, and with a still more considerable

derable alloy, it tinges glass of a blue colour.

COBALT is most strongly attracted by acid of sugar, which precipitates it from other acids, in the form of a pale rose-coloured powder; and as it is very difficult of solution in water, unless a great excess of acid be present, its power of attraction has not yet been compared with that of the acid of sorrel, which likewise precipitates cobalt from the muriatic, and other acids. The vitriolic is expelled by the muriatic acid, as may be shewn in various ways. Highly rectified spirit of wine refuses vitriol of cobalt, but not muriated cobalt. Since, therefore, a solution of this vitriol in marine acid, affords no precipitate on the addition of spirit of wine, it is evident that the vitriol must have been decomposed. Besides, muriated cobalt (but not vitriolated) yields sympathetic ink;

now a solution of vitriol, upon the addition of muriatic acid, (or of sea-salt, which contains it, and then the decomposition is effected by a double attraction), immediately acquires this property, and in a dry state of the air, writing is turned green, and becomes legible. I say, when the air is dry, for when the letters are invisible, if the paper be put over newly burned lime, or concentrated vitriolic acid, in a close phial, they soon become manifest. Fire, therefore, or heat, acts only by drying, which is agreeable to Hellot's explanation. Cobalt precipitated with phlogisticated alkali, is neither soluble in phlogisticated alkali, nor acids.

Acid of arsenic is incapable of taking cobalt from vinegar, at least it causes no precipitation. The other places remain to be further examined.

LXVII.

Column Fifty-sixth, Zinc.

ACID of sugar takes zinc from every other acid, and when united with it, immediately falls to the bottom in the form of a white powder; but the acid of sugar of milk yields to the vitriolic, and that of fat to the nitrous. Zinc precipitated by phlogisticated alkali is not acted upon by an excess of it; but it is taken up by acids. Vitriolic, nitrous, and muriatic acids, prevail over that of arsenic; but the acetous yields to it. Vitriolic acid comes before the muriatic; for vitriol of zinc, dissolved in acid of salt, is precipitated by spirit of wine. Acid of sorrel has not been tried; but if I mistake not, it will be found to expel the vitriolic.

LXVIII.

LXVIII.

Column Fifty-seventh, Antimony.

THE attractions of antimony have as yet been but little examined; the examination is indeed attended with difficulty, since the solutions require an excess of acid. The first place belongs to the acid of fat, and the next to the muriatic; the vitriolic is expelled by the saccharine. The vitriolic, nitrous, and muriatic, are superior to the arsenical; to which, however, the acetous yields. I have not yet been able to ascertain a greater number with accuracy.

LXIX.

LXIX.

Column Fifty-eighth, Manganese.

THE specific gravity of magnesia nigra, the property it possesses of tinging glass, and, above all, the white precipitate produced by phlogisticated alkali, in solutions made in every acid, led me, many years ago, to perceive distinctly that this substance contained a peculiar metal. Dr Gahn, who was formerly my pupil, first eliquated the regulus, which has most distinguishing properties; and since neither analytic experiments have resolved it into others, nor synthetic composed one with the same properties, it is proper to distinguish it. Manganese in its metallic state is hard, brittle, has a granular, white and shining fracture; and such is its refractoriness, that it is more difficult of fusion than iron,
whence

whence I at first conjectured, that it was the same as platina ; it seems to refuse sulphur ; it yields a perfectly pellucid and colourless vitriol, of which the crystals are parallelopipeds. The calx, when deprived of almost all its phlogiston, is black ; but when it has a sufficient quantity to be capable of solution in acids, it is white ; when in combination with a still larger portion, it acquires a reguline nature. The black calx, in the fire, gives an hyacinthine tinge to borax, and a purple one to microcosmic salt ; but on the addition of a sufficient quantity of phlogiston, both colours disappear. This metal parts with great difficulty from all its iron ; but who knows not the difficulty of separating the last vestiges of foreign matter, when it is surrounded by other particles, which attract them strongly, especially if the mixture be refractory ?

THE black calx is taken up indeed by the vitriolic and marine acids, but the solutions are coloured, and never without a tinge, unless an addition of sugar, or some other matter, be added to supply the necessary phlogiston; but it is perfectly dissolved in acids, either artificially phlogisticated, as those of vitriol and nitre, or those naturally containing inflammable matter, as those of lemon and tartar; and it decomposes them at the same time.

THE acids of sugar, tartar, sorrel, lemon, phosphorus, and fluor, expel the nitrous, vitriolic, and marine; for when vitriol of manganese is dissolved in them, there appear smaller crystals, easily soluble in spirit of wine, which totally rejects vitriol; and, moreover, the solution in which the crystalline grains are immersed, when poured off, afforded no precipitation on the addition of spirit of wine. The acids of
nitre,

nitre, fat, and arsenic, expel the acetous. The rest is doubtful.

IN the dry way, copper, iron, gold, silver, tin, and siderite, combine with manganese. The other metals remain to be tried. Liver of sulphur scarce separates the alloy of iron, but dissolves both metals together.

LXX.

Column Fifty-ninth, Siderite.

THIS metal, which renders iron cold-short, seems to me to be different from all others. The few circumstances which I have hitherto been able to observe concerning it, may be seen in my essay on that subject. Much remains for investigation ; and I have been obliged to put off my researches for want of materials to work upon. The three
common

common mineral acids dissolve it, but with difficulty. In the series of precipitations by metals, siderite seems to stand higher than lead. It cannot, any more than tin, be precipitated in a metallic form, but always falls down in the state of a calx.

SUCH is this extensive subject, and such a multitude of experiments and observations does it still demand. I have distinguished what is certain from that which remains doubtful, that it may appear what remains to be done by him who wishes to try his powers and patience in the cultivation of this science. The stations which are ambiguous or doubtful, have not been assigned totally without reason, though indeed insufficient to produce full conviction. Moreover, if I have any where erred, the condition of humanity must plead my excuse. I do not, however, doubt but
that

that many assertions, which shall seem obscure, or perhaps false, to some, will be quite plain and evident to him who shall seriously apply to this task.

E N D.

N O T E S

O N T H E

PRECEDING DISSERTATION.

P. 4.] **C**ONCERNING these admirable experiments of M. de Morveau, we have a very acute and pertinent observation by an author, frequently superficial. He remarks, that there is a source of error in them of which M. de Morveau was not aware, for the inferior surface of the highly polished plates, which are brought into contact with the mercury, being more or less readily dissolved by it, according to the nature of the metal, will acquire an unequal addition of matter; and hence the difference in the weights, necessary to separate the laminæ from the surface of the mercury, may arise, not from any difference of attractive power, but from inequality of mass. (Fourcroy, Leçons Elem. Diff. sur les Affinit.).

P. 32.] THE sentence beginning in l. 11. would be clearer, if placed in the following manner :

“ In the first place, we remark that a portion of phlogiston flies off in the inflammable air,” &c.

P. 47. l. 1. &c.] M. QUATREMERE D'ISJONVAL affirms, (*Collection de Memoires, Paris 1784, p 219. &c.*) that when solutions of muriated magnesia and muriated lime, and likewise of vitriolated volatile alkali and vitriolated magnesia, are mixed together, the precipitation which takes place, is without decomposition, and the effect of the strong attraction of one of the compounds for water. But the excessive ignorance this author betrays of the most common observations in chemistry, (for he affirms, that when nitrated lime and vitriolated tartar are mixed together, the latter salt is precipitated) shews that his opinion is not worthy of the slightest attention.

IT is more surprising that Mr Morveau, the translator and correspondent of Bergman, and, unquestionably, one of the most philosophic chemists in France, should put the following question, five years after it had been solved by our author, (N. Act. Upsal, V. III. 1775.) “ How does it happen that two salts, which
 “ when separate have a sufficient quantity of water
 “ for their solution, should, upon mixture, immediately yield crystals, as if the water had been attracted
 “ by spirit of wine? This a *totally new* question,” &c. (l. c. p. 221.).

P. 65. l. 20.] THE words *of the substances* may be struck out without injuring the sense; and the omission would make the sentence run smoother.

P. 77.]

P. 77.] NEITHER do the phænomena which attend the combustion of sulphur, nor others of the same nature, admit of rational explanation upon any principles hitherto known, unless we adopt Mr. Cavendish's discovery concerning the constituent parts of water. The experiments of that excellent chemist, in my opinion, lead to more speculations, and promise the solution of more phænomena, than any which have been published since the fundamental discovery of Dr Black. But I shall have occasion to consider them more particularly below.

P. 89. 32.] THIS conjecture of the author's would seem to be erroneous, for Mr Wiegleb (Crell's *Neuest Entdeck. Th. 11. p. 14. 1783.*) relates some experiments, from which it evidently appears, that fixed vegetable alkali has a stronger attraction for vitriolic acid, *viâ siccâ*, than the heavy earth $\frac{3}{8}$ ls of the heavy spar being exposed to a strong heat in a crucible, with $\frac{3}{4}$ vi of salt of tartar, was decomposed all but 28 grains. Mr Wiegleb adds, that this is a much easier process than that of Scheele and Bergman Dr Withering has some experiments (*Phil. Tr. v. lxxiv. p. 304. 1784.*) that exactly coincide with these, but Mr Wiegleb's seem to be of an earlier date. No mention is made by either of fossil alkali; but it may be supposed to agree with the vegetable. I have arranged these substances accordingly, but have drawn no line between them, since it is not absolutely cer-
X 2
tain,

tain (though I have little doubt of it) that pure fixed alkali will effect this change. That the aerial acid comes into action in the above mentioned experiment, there can be no doubt, for Mr Wiegleb makes express mention of an effervescence.

P. 96. l. 2.] WHENEVER the author disposes substances by conjecture or analogy, he takes care to inform his reader. As he therefore speaks positively in the present paragraph, it is to be concluded that he speaks from experiment. Dr Withering, however, (l. c.) affirms the contrary with great confidence. I have so often, says he, repeated these experiments, to satisfy myself and others, that I am persuaded the terra ponderosa caustica ought to be placed below the alkalis, exceptin the column appropriated to the vitriolic acid. Mr Kirwan, confiding in the accuracy of Bergman, asks, Whether a deception may not have arisen from the absorption of an excess of acid, by the alkalis that were added? It is likewise to be remembered, that when Dr Withering employed pure vegetable alkali, he obtained a precipitate, soluble neither in water nor acids, *viz.* a combination of the alkali and earth. The same precipitate likewise appeared when an aqueous solution of pure terra ponderosa was added to pure vegetable or fossil alkali, but none when it was added to pure volatile alkali. These precipitates are undoubtedly well worthy of farther examination. It must surely, *a priori*,

priori, seem just as extraordinary, that volatile alkali should throw down the heavy earth, as that the fixed alkalis should be precipitated by it. Meanwhile, till this matter is thoroughly cleared up, I have placed a note of interrogation after the heavy earth, in the table of words.

Ibid. note.] MR CAVENDISH found that the water proceeding from the deflagration of inflammable and dephlogisticated air, is always impregnated with nitrous acid, whenever those airs are exploded in such a proportion, that the burnt air is not much phlogisticated, from whatever substance the dephlogisticated air may have been procured. But if the proportion be such, that the burnt air is almost entirely phlogisticated, the condensed liquor is not at all acid, but seems pure water, without any addition whatever; and when they are mixed in this proportion, very little air remains, almost all being condensed. These phænomena may be explained, by supposing, either that nitrous acid, in small proportion, is a constituent part of dephlogisticated air, or that phlogisticated air is nitrous acid, with a larger proportion of phlogiston than nitrous air. To the latter supposition Mr Cavendish evidently inclines, and observes, that, in conformity to it, part of the phlogisticated air, with which the vital is debased, is, in his experiment, converted into nitrous acid, by the strong affinity of the latter to phlogiston. As a confirmation of his supposition,

X 3
position,

position, he remarks, that when nitre is deflagrated with charcoal, the acid is almost entirely converted into this kind of air.

THIS acute conjecture points to the origin of nitrous acid, a discovery which, since chemists have been so conversant with elastic fluids, has always seemed to be near at hand, though it has constantly eluded their grasp. For if it be true, it is reasonable to imagine that Nature has some process by which she disengages the acid, and perhaps, in the variety of her operations, another by which she again combines it. At all events, the subject is worth prosecuting. And it would seem advisable to expose nitrous air to various substances, by which we may expect to communicate phlogiston to it ; for although this has been already done, as by exposing it to liver of sulphur, and the result has been such as seems rather to favour Mr Cavendish's hypothesis, yet we are not enough acquainted with it to draw a certain conclusion.

ANOTHER method might be, to observe the effect of vital upon phlogisticated air, under as many different circumstances as can be imagined. Some experiments on inflammable air, to be mentioned hereafter, would seem to afford encouragement for such an investigation. These elastic fluids are indeed constantly present together in the atmosphere, but that is a situation not calculated for such observations. Might not the electric fluid be of great service here also ?

WE

WE are besides indebted to Mr Becker of Magdeburg, for some recent observations on the origin of the nitrous acid. In a pamphlet, (*Entdecktes Saltpeter-sauer in den Animalischen Aufleerungen*, Dessau. 1783), he rejects both the ancient and modern opinions concerning the generation of this acid, either as palpably false, or as unsupported by any adequate proof. He asserts, that the putrid fermentation is not at all necessary to its production. He found (Experiment I.) nitrous acid in cows urine, which had been exposed for eight days to the sun. He mixed some of the soakings of a dunghill with a ley of burnt sheeps dung, and chalk in powder. The mixture began to ferment on the following day, and on the fourth, the internal commotion having ceased, he found at the bottom of the phial. regular crystals of prismatic nitre.

IN a supplement to this publication, he tells us that he has found the full solution of the problem concerning the generation of nitre, and that the acid is not to be sought in the air, but in the vegetable kingdom, *by means of the excretions of animals*. "I found further, says he, that this kingdom affords not only the common fixed alkaline salt, but also a fixed-alkaline-animal neutral salt, which appeared on lixiviation, notwithstanding the dung was dried and burnt. It is truly surprizing, that during the burning of the straw or dung, its alkali, together with the acid contained in the dung, should not be destroyed by the

process, but should combine with each other. The farther I proceeded, the more I discovered. On examining the earth of stables and cow-houses, I found that its lixivium yielded prismatic nitre, while that of the dung would only afford small crystals, which required an addition of nitre, in order to be reduced to a prismatic form. Moreover, I can extract nitre at pleasure, in the course of three days, from the earth of stables and cow-houses, by using for saturation well purified potashes."

THESE experiments do not, indeed, shew the constituent parts of nitrous acid, but they may serve to warn us against false theories. I am sorry that I can give no account of the experiments and opinions of Mr Thouvenel, the successful candidate for the prize offered by the French Academy, having never yet been able to obtain a perusal of his dissertation.

P. III. l. 15.] IT may be worth while to examine into this matter a little more narrowly. The difference between neutral salts containing phlogisticated and dephlogisticated acids, is very striking, in many instances. Should we even admit, that the alkali contains a portion of the inflammable principle, and communicates it to the acid, there must still be a deficiency, *i. e.* less phlogiston than in common salt, unless it be supplied from some other quarter; and we might expect a sensible difference. It is not to be expected, from what is said of the attraction of vital air for
phlogiston,

phlogiston, that the aerial acid (supposing it to consist of these two substances) of the alkali will be decomposed by the dephlogisticated muriatic acid. I wish, however, that the experiment were made, with a view to the examination of the elastic fluid.

SINCE this part of the note was written, I have seen a paper on the dephlogisticated marine acid, by Mr Bertholet, (Journ. de Physique, Mai 1785.) who directed his attention, in some measure, to this very object. He boiled in an air-apparatus a mixture of fossil alkali and dephlogisticated marine acid, and found that the disengaged elastic fluid was at first aerial acid with common air; next, air of a purer kind; and, last of all, aerial acid again. From calcareous earth, *no aerial acid is disengaged, but only atmospheric air, which gradually becomes more and more pure, and is at last very pure dephlogisticated air.* This last experiment looks very like a confirmation of my conjecture, that the dephlogisticated acid gets phlogiston from the elastic fluid. But Mr Bertholet has, by no means, sufficiently investigated the problem, though what he observed may serve still further to shew that it is worthy of investigation.

THE atmospheric air, in the first experiment, was beforehand contained in the vessels. Whence the vital air that appears afterwards proceeds, it is not easy to tell. Can it come from the decomposition of water, which perhaps the strong attraction of the dephlogisticated acid may assist in accomplishing in a gentle heat?

Mr

Mr Bertholet himself, conformably with the new French hypothesis, deduces it from the dephlogistigated muriatic acid.

THE neutral salt, formed in this experiment, was exactly like common salt.

WHAT he says of volatile alkali, is very obscure. He perceived an effervescence, even when the alkali was caustic; and the elastic fluid was of a peculiar kind, and, as he thinks, is formed by the combination of volatile alkali, and the dephlogistigated air yielded, according to his hypothesis, by the acid.

POSSIBLY the acid, by attracting the phlogiston of the volatile alkali, may decompose part of it; and if so, the elastic fluid that is extricated will be the same as that which is obtained by the explosion of fulminating gold, (Scheele on air and fire, Bergman Opusc. vol. ii.); and the acid being thus reduced to common marine acid, will unite with the rest of the volatile alkali, and form sal ammoniac, which was the product obtained by Mr Bertholet.

P. 115. l. 11. 12 &c.] MR TILLET, who has lately (Mem. Paris. *année* 1780.) examined the action of nitrous acid upon gold, in the circumstances described by Mr Brandt, has been led to form an opposite opinion. He allows, that nitrous acid, under these circumstances, does actually *attack* gold *in leaves, and in a state of ductility*, but contends, that it does not really dissolve it either wholly or in part, keeping it only
mechanically

mechanically suspended. Whether he has brought any new experiments or arguments that prove his assertion satisfactorily, let the reader judge. He observes, and it was known before, 1. *That, if a little silver be added to nitrous acid containing gold, the latter metal will be precipitated.* The connection between mechanical suspension and this effect, is not very obvious; but, if we suppose the gold to be dissolved, then it may be said, that the phlogiston afforded by the silver is the cause of the precipitation; so that this phenomenon would appear to be rather unfavourable to the author's opinion, and so far unfavourable as to counterbalance all his other arguments.

2. GOLD thus precipitated, (1.) *notwithstanding its tender and spongy state, is not taken up by nitrous acid, however concentrated and assisted by heat.* It certainly seems extraordinary, that metallic particles, diffused through the substance of another metal, should be, in some measure, soluble; and yet, that these very particles, in a state of equal tenuity, should become insoluble, when the other metal has been removed. But the fact, however remarkable, can scarce be thought conclusive. It is the opposite of that case, in which the particles of a body, easily soluble by themselves, are yet prevented from being dissolved, by being mixed with a large proportion of an insoluble body.

3. MR TILLET found, that all the gold was deposited while the nitrous acid was passing through a filter of four folds of paper. Mr Brandt observed, that the gold
was

was deposited after the acid had stood some time, and also on agitation.

4. ON examining a drop of the acid with the microscope, Mr Tillet saw the particles of gold in their metallic state, floating in it. Can we suppose, that some particles are suspended, while others are dissolved? Or, may it be conjectured, that, as the noble calces easily recover their phlogiston, a source of error might arise from the exposure of the solution to the sun's rays? That such an accident might happen, appears from Mr Tillet's total silence with respect to this circumstance.

THE Commissioners, moreover, (l. c. p. 615.) observe, that it appears from several of their experiments, that the purest nitrous acid takes up (*se charge avec*) a few particles of gold.

P. 120. l. 7. 8.] THIS opinion concerning the cause of the corrosive nature of certain metallic salts, has been adopted and confirmed by many experiments by Mr Bertholet, [Journal de Medecine, 1780, p. 50. The same essay was likewise since reprinted, with additions, in the Mem. Par. for 1780.] Among his experiments, the following seem the most conclusive: Corrosive sublimate, exposed to heat, (not a violent degree), with oil, is, for the most part, reduced. A piece of flesh being put into a solution of this mercurial salt, a copious precipitation took place; the liquor now
reddened

reddened syrup of violets; whereas it had before turned it green. The precipitate was calomel.

PRECIPITATES of corrosive sublimate, whether with lime, or alkalis dissolved in nitrous acid, without effervescence or red vapours.

MERCURY dissolved in aqua regia yields corrosive sublimate; whence, as well as from other considerations, the author concludes, that the muriatic acid exists in corrosive sublimate, in a dephlogisticated state. He has since given (*Journ. de Phys. Mai 1785.*) a very beautiful and simple proof of the same position. By only adding the dephlogisticated acid to a nitrous solution of mercury, he obtains corrosive sublimate. Nitrous solutions of mercury become more corrosive, as they are more deprived of phlogiston.

FROM these, and some other experiments, the author thinks himself fully entitled to conclude, that the corrosive quality of metallic salts depends on their attraction for phlogiston.

P. 129.] NOTWITHSTANDING the strong attraction of the acid of sugar for lime, there are cases in which it will not show its presence. We have an instance of this important practical observation in Mr Scheele's and our author's analysis of the calculus. The former perceiving no precipitation to take place on the addition of acid of sugar, immediately concluded, that there was no lime present; but the latter having often observed, that a third substance superadded

to two already united, instead of effecting a separation, enters into close combination with them, suspected, that this might be the case here, especially as he knew, that the saccharine acid contains an unctuous matter, though of great subtilty. And upon burning some calculus to ashes, obtained a substance which exhibited the most unequivocal marks of calcareous earth. (Stockh. Transact. vol. xxxvii. p. 333.) Hence we learn, how desirable it is in chemistry to be possessed of more than a single test, as it is called, of different substances.

P. 139. l. 21.] THIS person probably is Mr Hermbstadt of Berlin; for we have a paper by him on this subject in Crell's *Neuest. Entdeck.* part 9. p. 6. It is obvious to suspect, that the vegetable acids of sugar and tartar, at least, and perhaps of vinegar, are, at bottom, one and the same, only modified by some addition, rather accidental than essential. This suspicion is favoured, not only by a resemblance in sensible qualities; but also, by the production of one or other of these acids, according to the different circumstances of a body, as in the several stages of fermentation. But such considerations are, by no means, fitted to decide any chemical question; they can only serve to suggest proper experiments. Accordingly, Mr Hermbstadt attempted such as were likely to decide the question: one part of acid of tartar, treated with four parts of nitrous acid, (of which the specific gravity was

to water as 41 : 28,) as in the preparation of saccharine acid, yielded some crystals like those of this latter acid, but only in the proportion of $\frac{1}{16}$ in one experiment, and about $\frac{1}{9}$ in another.

BUT upon adding four ounces of smoking nitrous acid to six drachms of acid of tartar, and abstracting it with a brisk fire, he obtained four drachms and two scruples of columnar crystals, which produced, in a great number of experiments, the same effects as the acid from sugar, and, in many respects, different from that of tartar. Though such numerous proofs of coincidence scarce leave any doubt, yet it is strange, that Mr Hernibstadt should neglect what may be considered as the *experimentum crucis*, the precipitation of a solution of gypsum. He promised, indeed, more experiments; but I have not been able to find them, either in the continuation of Crell's Journal, or any other work. It is however to be remembered, that Bergman treated the acid of tartar with nitrous acid, without obtaining any acid of sugar, [Opusc. vol. i.] Nor is it to be forgotten, that two vegetable or animal acids are very frequently present in the same compound, as in the case of sugar of milk and microcosmic salt. But we can surely scarce suppose, that so large a proportion of acid of sugar should be accidentally present.

MR WESTRUMB, another very intelligent German chemist, obtained four drachms, two scruples of acid of sugar, from an ounce of tartar, treated with nitrous acid. His method of proceeding is worth mentioning.

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To an ounce of tartar, he added two ounces of weak nitrous acid, and dissolved it by means of a gentle heat. The liquor was then exposed to evaporation in the sun's rays, and, in some days, he observed crystals of nitre formed, amounting to two drachms, five grains; when it would yield no more of these, two ounces of strong nitrous acid were added to the acid and viscid residuum; when the phial had stood a short time, red vapours began to arise; the addition of strong nitrous acid was repeated, as long as the liquor retained any viscosity, or any red vapours arose, in which four ounces of nitrous acid were consumed in all, and the quantity of laccharine acid obtained was four drachms, two scruples.

P. 158.] INSTEAD of obtaining phosphoric acid by the tedious and wasteful method of combustion in the air, I should think chemists would procure it by decomposing phosphorus with nitrous acid, as Mr Lavoisier directs, *Mem. Paris, ann. 1780, p. 349. & seq.* Nothing is required to procure the acid in a state of as great purity, as by combustion, and with the greatest ease and expedition, but a prudent management of the fire.

P. 165.] THE processes mentioned in this page, suggest what has been sought by so many chemists, an unexceptionable method of preparing Prussian or phlogisticated alkali; all that remains to be done after
the

the acid has been once obtained, is to saturate it with an alkali or with an absorbent earth, which, if we may judge from several instances mentioned in the text, seems to answer equally well. But a shorter process occurred, in consequence of the discovery of the nature of phlogisticated alkali, to Mr Scheele, and much about the same time to Mr Westrumb.

THE method of the latter is as follows: he saturates pure vegetable alkali by frequently boiling it with well-washed Prussian blue. He then boils the filtered liquor with white lead, in order to separate any sulphureous or phlogistic particles that may happen to adhere to it. He then adds vinegar, which when it has been distilled in tin-vessels, occasions the precipitation of a white matter in great abundance; but not a particle of blue is seen to fall. He then, in conformity with Scopoli's advice, exposes the liquor to the sun's rays, and keeps it in that situation as long as any red precipitate is observed to separate. Upon this the lixivium is filtered, and then mixed with a double quantity of highly rectified spirit of wine, which throws down the proper salt of the *lixivium sanguinis* in the form of shining flocculi; they are to be separated by means of the filter, and all the saline matter soluble in spirit of wine is to be extracted by that menstruum. The solution of the salt in water, of a bright yellow colour; does not shew the least tinge of iron upon the addition of an acid; precipi-

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tates

tates that metal of a beautiful blue colour, copper red, &c.

MR SCHEELÉ's method is far less complicated. He extracts, as before, Prussian blue, with perfectly caustic fixed alkali, and then mixing highly rectified spirit of wine with the filtered liquor, he obtains the salt in the form of flocculi. Mr Scheele adds, that he is thoroughly convinced of the inefficacy of every other method of purifying the *lixivium sanguinis*; for if the yellow solution be properly boiled with muriatic or vitriolic acid, Prussian blue will always be separated. The salt obtained by the process just described, is not liable to alteration in the open air; for the iron holds the tinging acid in closer union with the alkali, and fixes it so that it cannot be dislodged by the aerial acid, which otherwise would happen, was it not combined with iron or some other metal in the tinging lixivium.

P. 187. § 42. Magnesia.] MR BUTINI of Geneva (*Nouv. Observ. et Recherch. sur la Magnésie. A Genève.*) having lately published several curious observations on magnesia, which have not, as far as I know, been laid before the English reader, I am tempted to give a short account of them, although they are not so immediately connected with the doctrine of attractions. He was not acquainted with the dissertation of Bergman on this earth; but he nearly agrees with him, in saying that an ounce of distilled

water

water is capable of dissolving a grain, or at most $1\frac{1}{2}$ grain of magnesia, whereas the same quantity of aerated water takes up thirteen grains. He found that magnesia does not at first dissolve in aerated water, but decomposes it by attracting the fixed air; when once saturated, it dissolves without decomposition; in its ordinary state, therefore, this earth is not saturated with aerial acid, the alkali used for its precipitation not supplying it with a sufficient quantity. Mr Butini determines by exact experiments, that saturated magnesia contains $\frac{1}{30}$ of the aerial acid, more than in its ordinary state. The solution in aerated water in the proportion of 1 : 64, becomes turbid in a temperature of 158° of Fahrenheit. But one of the most remarkable among his observations, is, that water may be over-saturated with magnesia, and yet pass through the filter, and seem clear. Such a solution is obtained by immediately filtering the water in which Epsom salt has been decomposed; if it be heated to 158° Fahrenheit, (which may be done in the palm of the hand), it lets fall its earth, which is redissolved when the liquor cools to about 59° . This is a very amusing experiment.

THE spontaneous crystallization is also a new and curious phenomenon. It will abandon the water, even when that is not saturated, in order to arrange its integrant parts into regular forms. The crystals are hemispherical *matrices*, consisting of needles, from the length of half a line, to that of five or six lines,

which are transparent hexaedral prisms, terminated by an hexagonal plane.

WHEN it is made to crystallize in a temperature of 59° — 62° , two kinds of crystals are formed, *viz.* groups of needles and solitary *blocks*, of which the shape is not exactly defined, though it is to be referred to that of an hexaedral prism, terminated by an hexagonal pyramid. In a heat of 39° to 41° , nothing but blocks appear; and again from the 73° to the 77° , the needles only are formed.

By repeated or violent calcination, magnesia loses its property of easy solubility in acids. Its particles, without acquiring a greater degree of mutual cohesion, gain a remarkable hardness, whence they become capable of scratching steel, &c. Water does not dissolve above $\frac{1}{9792}$ of calcined magnesia, nor does the solution yield any crystals. During calcination, this earth emits a phosphoric light, and adheres with great tenacity to cold bodies, it also presents that appearance of fluidity, which is remarked in gypsum. Calcined magnesia, exposed to an atmosphere of aerial acid, or left in a vessel covered only with a piece of loose paper, does not recover its fixed air.

NEUTRAL salts heighten the solvent power of water, while alkalis diminish it.

To these experiments of Mr Butini, let me be allowed to subjoin some of another author, not less remarkable, though they relate to another part of the chemical history of magnesia, *viz.* its combination with acids.

MR

MR QUATREMERE D'ISJONVAL (Coll. des Mémoires, p. 207.) gives an account of his having obtained permanent compounds, with magnesia and nitrous acid; and what is more extraordinary still, with muriatic acid likewise. To obtain this effect with the first, he precipitated purified Epsom salt, dissolved in cold water, with fixed vegetable alkali; he then saturated the magnesia with pure nitrous acid, and evaporated the solution, which at first yielded nitre, on account of some alkali carried down by the precipitate. After this was separated, he redissolved the saline magma, and evaporated it again: These operations he repeated two or three times, till some rudiments of crystals appeared, which being redissolved, afforded, on evaporation, crystals that had a stronger tendency to effloresce than deliquesce, even in a moist place. They have the form of four-sided prisms, truncated acutely. With muriatic acid he proceeds much in the same manner, taking care to saturate the acid completely.

HE subjoins two cautions of importance for the more certain and speedy production of these crystals: 1. That not above half the magnesia should be precipitated, for he is afraid of the presence of calcareous earth; and 2. That the magnesia should be dissolved in the acid, while it is yet in the tender form of a precipitate.

I WAS unwilling to with-hold these curious observations of a chemist who had carried away the prize, when Bergman was his competitor; but, whatever

authority this may add to his name, I think that he who shall peruse his writings, will be careful how he gives entire credit to his assertions, before he has repeated his experiments, though it must be confessed, that they receive some authenticity from a letter of Mr de Morveau (p. 222.) to whom Mr D'Isjonval sent specimens of his crystals.

P. 198. *paragraph B.*] I MUST confess myself ignorant of any good reason for believing *phlogisticated*, *foul*, or *corrupted* air, to be a modification of vital air. Mr Kirwan's reasons for supposing it to be aerial acid, combined with more phlogiston, convey to me no sort of conviction. Mr Cavendish has thrown a ray of light upon this obscure substance, as I have already mentioned, and unless his rational conjecture should be ripened into a discovery, it is better to own our entire ignorance of the nature of this elastic fluid, than to content ourselves with any of the explanations that have yet been offered.

P. 199. & seq. *paragraph B.*] THE connection between nitrous acid and vital air now begins to appear in a very different light. To suppose that these two substances were but modifications of one and the same, was both natural and allowable, when vital air was first procured from nitre; but when it appeared, in the progress of enquiry, that so many other bodies, free from all suspicion of any mixture of nitrous acid,
were:

were found to yield the same fluid, the opinion could be no longer tenable, nor is it, by any means, conformable to the usual severity of the author's logic. The experiments of Mr Cavendish and Mr Watt shew, that the common office of nitrous acid and other substances, is merely to dephlogisticate water. The latter, who made an attempt to recover the nitrous acid, found, upon procuring vital air from this acid and earths, that, however thoroughly the acid and earth might be dephlogisticated, the acid always became highly phlogisticated after the process. (Ph. Tr. vol. lxxiv. p. 338.). He found, moreover, in one experiment, that thirty-six ounces measure of vital air were produced, and only five grains of weak nitrous acid missing; and in another, thirty-four grains weight of the same air were produced, with the loss of only two grains of *real* acid, p. 343.

FURTHER, when vital air is obtained from vitriolic salts, vitriolic acid air appears, at the same time, even when the salts are not known to contain any phlogistic matter, p. 344.

P. 208. & seq. *paragraph C.*] It is now no longer probable, either that Mr Kirwan's or Mr Scheele's opinion will be confirmed. Both must give way to the discovery of Mr Cavendish, concerning the constituent parts of water. By some experiments made in the summer of 1781, and read before the Royal Society in 1784, he found, that, upon

firing together inflammable and vital air in close vessels, they were condensed into water. Other chemists, both at home and abroad, have now amply confirmed this unexpected observation, as Dr Priestley, S. Iaudriani at Milan, and Mr Lavoisier at Paris, who has used very large quantities in his experiments, but has shamefully attempted to appropriate the discovery to himself; and he is accordingly mentioned in many foreign journals as the first discoverer. Dr Priestley found, that after inflammable and vital air had been deflagrated together, and the vessel had cooled to the temperature of the atmosphere, as much mercury or water, in whichever of these liquids the mouth was immersed, entered, as was sufficient to fill it within $\frac{1}{200}$ part of its contents: moreover, when the moisture adhering to the glass was wiped off with a piece of sponge paper, first carefully weighed, it was found exactly, or very nearly, equal to the airs employed. (Mr Watt, Ph Transf. vol. lxxiv. p. 332.). This discovery is so much the more to be admired, as no hints had been thrown out by any other author which could lead to it, nor could it have been surmised by any analogical reasoning. It promises, however, to furnish explanations of many of the obscurest operations, both in art and nature. Thus the generation of vital air, the disappearance of vital and nitrous air, when mixed together, the production of vital air by vegetables, the diminution of the air in the combustion of sulphur, phosphorus, &c. are now no longer

ger phænomena that require, for their explanation, hypotheses uncountenanced or contradicted by experiments. But Mr Cavendish's discovery leads to much wider views. It suggests new experiments on the increase of weight of calcined metals, a problem still remaining to be solved, notwithstanding so many late attempts. The first object of those who shall now labour on this subject, should be to ascertain, whether a quantity of water, equal to the difference of weight, is generated during calcination. The general principle is equally applicable to volcanos and to statical physiology; for it is now obvious to suspect that the exhalation from the lungs is not thrown off in that form by animals, but rather generated by the mixture of the dephlogisticated part of the common air with phlogiston. But this is not the proper place to indulge in such speculations.

To offer any arguments against Mr Scheele's doctrine of the composition of heat, would be now superfluous, since Mr Kirwan (Notes to the Treatise on Air and Fire) and Fontana (Opusc. Litt. à S. Adolph. Murray) have abundantly confuted it. Bergman, himself, notwithstanding he has adapted several explanations to it, seems to acknowledge at last, that it is liable to insurmountable objections. One alone is sufficient: that loss of weight, which must ensue if the vital air and phlogiston pass off through the vessels in the form of heat, is not observed. But it is a proof of Mr Scheele's acuteness, that he first perceived

ved the necessity of some substance containing vital air and phlogiston in so many chemical experiments.

MR KIRWAN's explanation, is equally inadmissible ; for Mr Cavendish has shewn, in the most satisfactory manner, that no fixed air is generated by the mixture of nitrous and vital air, any more than in the explosion of inflammable air ; or at least, if any be generated, it is so small a quantity, " as to elude the " nicest test we have." (Ph. Tr. vol. lxxiv. p. 121. 122. ; and 172. 173.)

P. 211. l. 3. and 4.] MR SENEBIER (*Recherches sur l'air inflammable*) has found that inflammable air actually does change vital air in a length of time. By keeping these substances over water, he observed that a diminution took place, and that the residuum did not undergo any alteration on the addition of nitrous air. From what Mr Kirwan says, (Ph. Tr. vol. lxxiv. p. 168.) it seems that Dr Priestley has made observations to the same purport ; for he tells us, that the Doctor has discovered, since his last publication, that inflammable and dephlogisticated air will unite.

P. 223. l. 5. & seq.] PRECIPITATE *per se*, and red precipitate, are soluble in marine acid, and during the solution, nothing is disengaged, but a great heat is produced, as in the slaking of quicklime ; the
salt

salt which is obtained by reducing the solution to crystals, is corrosive sublimate.

THIS observation does not coincide with the experiment of Bergman, who affirms, that calcined mercury is reduced by digestion in muriatic acid. I cannot guess how he could have made his experiment; for whenever I have added precipitate *per se* to muriatic acid, I have always observed solution to take place with the production of much heat, and have obtained crystals of corrosive sublimate on refrigeration. It is true indeed, that when red precipitate is employed, a black powder, consisting of mercury, separates; but this mercury is not any of the calx revived; it separates during the time of solution, because the muriatic dissolves no mercury *that is not combined with vital air*; and this mercury happened to be mixed with the calx; so, if we take notice of what passes in the preparation of red precipitate, it will be seen that first nitrous air, and afterwards red precipitate pass over, long before the mercury rises. May not Bergman have used this precipitate, and thus been led into a mistake? He knew not how to explain the reduction. Mr Kirwan (Phil. Transf. vol. lxxiv. p. 159.) says that the reduction is owing to the expulsion of the fixed air from the mercurial calx; which fixed air, at the moment of its expulsion, is decomposed, leaving its phlogiston to the mercury, which is thereby revived. But this explanation is inadmissible, since

Since no reduction takes place, as I have already observed. (*Pelletier J. de Phys. Mai, 1785.*)

P. 253. l. 11. & seq.] DR PRIESTLEY says, that the iron is *superphlogificated*, and has lately assured us, [Phil. Transf. vol. lxxiii.] that he has frequently repeated the experiment with the same result. I fear, that neither Priestley nor Bergman have examined the state of the iron, otherwise than superficially. Perhaps, on a more accurate examination, something might appear that would lead to an explanation of the phænomenon.

P. 257. l. 4. & seq.] CRELL advises (Chem. Anal. St. i. p. 94.) to use in this experiment another equal and similar vessel, containing a quantity of water A, of equal weight, and at the same temperature (32° Fahr.) with the ice B; let the two vessels, he adds, be placed near one another, and observe how long a time A requires to attain the temperature of the room. Moreover, observe how long a time B requires, $1/t$, to melt, and, $2d$, to attain the temperature of the room. Next, multiply the degree of heat acquired by A, by the time B $1/t$, took to melt, and, $2d$, to attain the temperature of the atmosphere. Then, supposing the degrees of the thermometer to correspond to equal accessions of the matter of heat, we may say, as much heat, (*i. e.* so many particles of fire),

as is sufficient to raise the thermometer to a certain heat, has such a weight.

I HAVE heard, that one of those Philosophers who believe heat to be merely a quality, has made the experiment proposed by Bergman, with this strange result, that, during the melting of ice, a diminution of *absolute* gravity takes place. If my information be right, I should think such a conclusion could prove nothing, but either the difficulty of making the experiment, without suffering some of the vapours to escape, or else the carelessness of the observer.

P. 258. 259. 260.] MR LAVOISIER and De la Place have lately given the following table of specific heats :

Common water,	-	-	1,
Sheet iron,	-	-	0,109985
Glass without lead, or crystal,	-	-	0,1929
Mercury,	-	-	0,029
Quicklime,	-	-	0,21689
Mixture of water and quicklime, in the proportion of 9 to 16,	-	-	0,334597
Oil of vitriol, (spec. grav. 1,87058,)			0,60362
Mixture of this oil with water, in the proportion of 4 to 5,	-	-	0,663102
Nitrous acid, (not smoking, specific gra- vity, 1,29895,)	-	-	0,661391
			Mixture

Mixture of this acid with quicklime, in		
the proportion of $9\frac{1}{3}$ to 1,	-	0,61895
Mixture of 1 part of nitre with 8 of		
water,	-	0,8167

THE ingenious machine, contrived for the purpose of measuring the specific heat of bodies, by these gentlemen, consists principally of three cavities inclosed in one another. The outermost is filled with pounded ice, which is designed to intercept the influence of the atmosphere upon the ice contained in the middle cavity. This latter is the real subject of the experiment, and the quantity of it melted by the bodies which are placed in the innermost cavity, gives the proportion of their specific heats, which are evidently as the quantity of water obtained. But there is reason to fear lest this ingenious and promising contrivance should fail of answering the end proposed; for Mr Wedgewood, who repeated some of the experiments, obtained the most opposite results, when the same body was heated to the same degree. His disappointment arose chiefly from two causes; the first of which was the absorption of the water by the pores of the ice; for, though the French Philosophers pretend, that no error can arise from this cause, since the ice has already imbibed as much water as it can, yet it is obvious, that, as the precise degree of force with which the pounded ice is pressed together cannot be adjusted, more or less water will be sucked up,

up, as it forms a less or more compact body. The other difficulty seems still more insuperable. Mr Wedgewood found, that the two processes of freezing and thawing were going on at the same time :—whether it be, that water in the state of vapour is liable to freeze in a higher temperature than when liquid, as Mr Wedgewood conjectures, or the ordinary absorption of heat by evaporation alone produces the effect, without any such disposition in the vapour. At all events, the present table, as well as those which Mr Lavoisier and De la Place promise, must be received with diffidence, till these impediments to accuracy be removed.

P. 263. *note.*] THE substance mentioned in this note, is called black wadd ; by Da Costa, *ochra friabilis nigra*. Its remarkable property of taking fire when mixed with oil, was first discovered accidentally at a painter's in Derby in 1752. Mr Wedgewood has lately (Phil. Transf. vol. lxxiii. p. 284.) published an analysis of it. He finds it to consist of insoluble earth, chiefly micaceous, of lead, iron, and manganese.

22 parts contain

of earth about	-	2
of lead	-	1
of iron	-	$9\frac{1}{2}$
of manganese	-	$9\frac{1}{2}$
		<hr/>
		22

P. 268.

P. 268. 269.] THIS analysis of charcoal differs exceedingly from that of Dr Priestley. He obtained not the least particle of aerial acid from charcoal, when it had been perfectly well burned; but the whole quantity was converted, by means of burning lens, into inflammable air, except a very inconsiderable portion of ashes. (Phil. Transf. vol. lxxiii. p. 411.)

P. 273.] IT is now completely ascertained by the experiments of Mr Hutchins at Hudson's bay, that the freezing point of mercury corresponds to the 40th degree below 0 of Fahrenheit's thermometer; therefore the numbers in the text must be much reduced. The other data of Dr Crawford, *viz.* the conversion of vital into fixed or phlogisticated air, have, by no means, the certainty of established principles. We must now look for the origin of the heat, in the condensation of vital air into water by phlogiston. And thus we have Mr Cavendish's discovery extended to another of the most obscure and familiar phænomena in nature.

P. 278.] BEFORE the publication of Mr Cavendish's paper on air, (Phil. Transf. vol. lxxiv. p. 119. & seq.) Mr Kirwan seems to have almost succeeded in persuading chemists, that fixed air is generated in phlogistic processes, by the union of vital air with phlogiston. Others had thrown it out long before as a probable supposition; but Mr Kirwan was, I think,
the

the first, who, by collecting and arranging the numerous facts published by different authors, gave the opinion a great degree of plausibility. Still, however, the complete proof, from unequivocal, analytical, and synthetical experiments, was wanting, and many of the most important cases of phlogistication gave no sort of countenance to the supposition.

MR CAVENDISH, by a rigorous examination of the arguments, has fairly reduced them within a very narrow compass. In the first place, he justly observes, that all experiments, in which any organised bodies are employed, must be set aside. He is inclined, likewise, to consider the experiments with the electric spark as equivocal ; being of opinion, that when turnsol is used, the aerial acid may arise from the burning of this vegetable matter ; and, in the case of lime-water, from some impurity in the tube, or else from some inflammable matter in the lime.

THERE remain then but four cases ; the calcination of metals, the combustion of sulphur or phosphorus, the mixture of nitrous air, and the explosion of inflammable with vital air.

NEITHER in the combustion of sulphur and phosphorus, nor in the explosion of inflammable air, has any vestige of aerial acid been perceived. That this is also the case in the mixture of nitrous air, Mr Cavendish has clearly shown, contrary to the general supposition, as I have already observed.

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WE have, therefore, left, for the support of so important and extensive a doctrine, only the calcination of metals : And in examining these experiments, made with care and close vessels, we do not find any evidence of the generation of fixed air. Mr Lavoisier and Dr Priestley found none in the air in which they had formed their experiments ; and, if it be said, that the metallic calces absorbed it, it is answered, that none has been extracted from calces so prepared. It is indeed true, that metallic calces prepared in open vessels, or such as have lain long exposed to the atmosphere, contain aerial acid ; but here the atmosphere is an evident source from which it might arise.

MR KIRWAN endeavours to remove these objections, by adducing several experiments, which show, that aerial acid exists in very sparing quantities in the atmosphere, and by representing it as improbable, that metals, during their calcination, should attract it ; because lime, exposed to a red heat ever so long, does not regain any. He insists upon what he had formerly advanced, that the revivification of certain mercurial calces, and the production of vital air, is owing to the decomposition of the aerial acid contained in the calces.

HE thinks his opinion strongly corroborated by an experiment of Mr Lussone, in which filings of zinc having been digested with caustic alkali, an effervescence was observed on the addition of an acid ; but Mr Cavendish supposes, that the effervescence arose, not
from

from the expulsion of aerial acid from the alkali, but of inflammable air from the incompletely dissolved zinc.

WITH respect to the experiment of Dr Priestley, mentioned in the text, Mr Cavendish relates an experiment, which seems to render it probable that the aerial acid proceeds from plumbago and other impurities contained in the iron : 500 grains of red precipitate, mixed with 1000 of iron filings, yielded 7800 grain measures of aerial acid ; and 2400, partly of vital, and partly inflammable air. But 500 grains of the same red precipitate yielded 9200 of aerial acid, and 4200 of indifferent vital air ; when they were mixed the plumbago and other impurities, which were the residuum of 1000 grains of iron filings, dissolved in diluted vitriolic acid. Hence, as more aerial acid was produced when the red precipitate was mixed only with the impurities, than with the iron filings themselves, it should seem to follow, that its production was owing, not to the iron, but to the plumbago, which is known to contain a great deal of it. As, however, it was found, that the iron filings were mixed with $\frac{1}{13}$ of their weight of brass, and, as more fixed air was produced, than the plumbago usually contained in 1000 grains of iron can supply, (which is Mr Kirwan's objection), Mr Cavendish candidly acknowledges, that the experiment ought to be repeated in a more accurate matter.

MR KIRWAN, besides, insists upon the diminution of common acid by the electric spark, as the most convincing argument in favour of his opinion. An experiment, too, in which Dr Priestley having amalgamated lead with mercury, obtained aerial acid from the black powder into which the lead was converted, seems really favourable to him.

SUCH is the state of a doctrine which so widely influences the theory of chemistry. Every one must acknowledge, that much stronger proofs must be adduced before it can be received as a fundamental proposition. Now, when we know that vital air and phlogiston constitute water, and that this will sufficiently account for the diminution of the air, it is no longer a necessary hypothesis: And this very discovery seems to give the opinion a general appearance of improbability, which the few facts that yet remain to countenance it, do not, by any means, outweigh; nay, it is probable, that these facts, as they are more narrowly scrutinised, will put on a different aspect, as has already happened in the mixture of nitrous and vital or common air. May not some such experiments as I have proposed above, for exploring the nature of phlogisticated air, serve to show whether aerial acid is really a compound of phlogiston and some other substance?

P. 285. *Æther*.] THE reader will surely excuse me if I digress a little from the subject of attractions, and the text of the author, in order to give him a
short

short account of some late experiments of Mr Scheele on this substance. They are to be found in the Stockholm Transactions, part iii. for the year 1782. Mr Scheele has not indeed yet been able fully to clear up the obscure theory of the generation of æther; but his experiments have led him to some new views.

WHEN vitriolic æther is prepared in a large retort, and a brisk heat is applied towards the last, volatile sulphureous acid is obtained together with vinegar, but no vestige of aerial acid:—when to an ounce of pounded manganese, half that quantity of vitriolic acid, and an ounce of strong spirit of wine was added, he got both vinegar and aerial acid, and found in the retort vitriolated manganese, without any excess of acid. He found that vitriolic and muriatic acids are constituent parts of their respective æthers, but in exceedingly small proportions. Besides zinc, antimony, and tin, by the intervention of which, it is well known that muriatic æther may be made, he obtained æther by a solution of bismuth in aqua regia, evaporated to the thickness of a syrup, and of crocus martis (iron filings will not answer the purpose) in muriatic acid. He also obtained æther by saturating spirit of wine with fluor acid air, and adding manganese. No acerous æther is to be obtained by the process of the Count de Lauraguais, notwithstanding almost all chemical writers, except Poerner, have admitted that process as an effectual one: Mr Scheele, however,

found a way of preparing acetous æther, and that, in greater quantity than any other kind of æther (this observation is surely important in practice) by adding to strong vinegar a little vitriolic, nitrous, muriatic, or fluor acid. Acetous æther is more easy of decomposition than any other. No æther could be procured with phosphoric acid, nor any with salt of benzoïn alone, though the latter yields some with the help of muriatic acid. Neither did his trials succeed with acid of tartar, of lemons, of borax, of amber, and several compound salts.

CONCERNING the theory, he observes, that though it may seem, that some substance, which has an attraction for the phlogiston of spirit of wine must be brought into action; yet this supposition can scarce be applied to the acetous æther, or that of benzoïn, or to the acids of fluor and sea-salt. But granting that these substances actually do attract phlogiston, how is the *oil of spirit of wine* itself, or the æther, separated from the water with which it was before united? Perhaps this phænomenon may be explained in the same way as the separation of sulphur from hepatic air: this latter is soluble like spirit of wine in water, and consists of phlogiston, sulphur, and the principle of heat. On the accession of a body that separates the phlogiston of this air, the principle of heat escapes, and the sulphur is precipitated. In applying this supposition, Mr Scheele observes, that manganese has a strong attraction for the inflammable principle

principle when an acid acts upon it. This metallic calx, spirit of wine, and vitriolic or muriatic acid being added together, the former attracts part of its inflammable principle from the spirit, whence the heat (which is so considerable, that this mixture boiled of itself) escapes, and the subtile oil or the æther is separated from the water. The portion of acid in highly-rectified æther, is very insignificant, though it can be made obvious. The small quantity of acetous and aerial acid, which he has observed in some distillations, proceeds from the decomposition of a small portion of æther ; for it is very probable, that the oil of spirit of wine consists of acetous acid and the principle of inflammability.

P. 318. Siderite.] THIS supposed new metal, siderite, [*Hydrosyrum, Wassereisen*] has been reduced by the first discoverer, Mr Meyer of Stettin, to a mere composition of iron and phosphoric acid. The reader will be best pleased with his own reflections on the subject. “ It is, says he, (Crell’s *Chemische Annalen*, B. i. St. 3.) but too easy to fall into mistakes “ in chemistry ; a truth daily confirmed by the number of disputed and contradictory experiments, and, “ of which, I myself probably furnish a fresh example. For my new metal, obtained from cast iron, that was run from a marshy ore, of which I “ have treated in the observations of the Berlin Society

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“ ciety

“ ciety * is, in all probability, neither more nor less
 “ than iron combined with phosphoric acid. My rea-
 “ sons for this opinion are the following. I dissolved
 “ some of my supposed new metal in vitriolic acid,
 “ taking care to use more acid than was necessary for
 “ the solution. I obtained in the retort a gray
 “ powder, and some sulphur appeared on its neck.
 “ Upon dissolving the gray powder, and evaporating
 “ the solution, I obtained a thick brown lixivium,
 “ in which, when it had stood still for a considerable
 “ time, some crystals of true martial vitriol shot:
 “ The remainder of the ley shewed the same phæ-
 “ nomena, as those I have noticed in the above men-
 “ tioned papers. Hence it was too apparent, that
 “ this metallic substance contained a large quantity of
 “ iron. But with what could it be combined? I
 “ could think of nothing but phosphoric acid.

“ HAVING poured a little water upon 20 grains of
 “ iron that had been fluxed with inflammable matter,
 “ and afterwards forged, I dropped into it a little phos-
 “ phoric acid, procured by the burning of phosphorus,
 “ and applied heat. The acid attacked the iron, and
 “ what was dissolved formed a gray powder. I ad-
 “ ded, by degrees, acid enough to dissolve all the i-
 “ ron, and then left it to dry by spontaneous evapo-
 “ ration. The gray powder, when dry, weighed
 “ $55\frac{1}{2}$ grains. Upon trying to fuse half a drachm of
 “ this with 20 grains of glass of borax, I found that
 “ it

* B. ii. p. 334. ; and B. iii. p. 380.

“ it did not flow well : nor when 20 grains more
“ were added, did it run into complete fusion. I
“ found in the glass particles of metal that were melt-
“ ed into grains not perfectly round, which were al-
“ so found to be very brittle, fused with difficulty
“ under the blow-pipe, and were converted into
“ scorixæ. The magnet had but little effect on them,
“ attracting only some small particles. Upon the re-
“ maining earth I poured oil of vitriol, diluted with
“ an equal quantity of water ; it was left to dry, and
“ then dissolved in a very small quantity of water,
“ and filtered it. Upon mixing this solution with wa-
“ ter, it became milk-white, and there fell down a
“ considerable quantity of white earth, in appear-
“ ance like the earth of siderite. I have not yet
“ been able to repeat and continue these experi-
“ ments ; but have no doubt of their being confirm-
“ ed ; and, in that case, I must alter the title of my
“ essays ; but I hope the essays are not without their
“ use. What a plentiful source of phosphoric acid
“ would be opened to us, if it were but easy to se-
“ parate ? The close combination of this acid with
“ iron, would also be remarkable.

“ BERGMAN has adopted my water-iron (Wasser-
“ eisen) as a new metal, under the title of siderum.”

WHAT Mr Meyer gathers from these two experi-
ments, is confirmed by Assessor Klaproth of Berlin,
who, by a remarkable coincidence, came to the very
same conclusion, without any communication with Mr
Meyer.

Meyer. He did not attempt to establish his opinion by analytical experiments, as he conceived that it would be difficult to separate the iron and acid, either by phlogiston or any other way. He found, however, the artificial compound of phosphoric acid and iron, to agree in its properties with the *calx sideri alba* obtained by Bergman; and Meyer from cold-short iron. Native Prussian blue contains this combination in much larger proportion.

* * * * *

SINCE the first publication of this dissertation in 1775, besides many alterations which totally change the disposition of it, not less than nine new columns have been added, which, if all the rectangles were filled up, make $9 \times 50 = 450$ new rectangles. I have no doubt but that an equal or a greater number of additions will hereafter be made in an equal number of years. Even since the publication of the third volume of the *Opuscula* in 1783, two, or perhaps three substances have been discovered which will claim a place on the table of elective attractions; these are what Mr Scheele considers as the acid inherent in tungstein, or *lapis ponderosus*, the metal which Messrs Luyart obtained from tungstein; for Wolfram only differs from it in being combined with iron and manganese, and the acid of the silk-worm, and some other insects, described by Mr Chauffier in the Dijon Memoires for 1783. Little, I presume, is as yet known concerning

concerning the elective attractions of these substances. Mr Scheele tells us, that the tungstein acid, as he supposes it to be, when combined with volatile alkali, decomposes nitrated lime, by a double elective attraction, and regenerates tungstein. He adds, that it produces no change on solutions of alum or vitriolated lime, but it decomposes acetated ponderous earth, the precipitate being quite insoluble in water; that vitriolated iron, zinc, and copper, nitrated lead, silver, and mercury, with acetated lead, are precipitated white, and muriated tin-blue; and that corrosive sublimate is not changed. All this was well known to Bergman; yet he has made no use of it, perhaps wisely judging that the experiments of Mr Scheele, as well as his own, could not be much relied upon, on account of the small quantity of matter they had to work upon: And, in fact, Messrs Luyart found, that what the Swedish chemists had taken for the acid of tungstein, was a triple salt, containing, besides the substance furnished by the stone, some of the acid and alkali employed in extracting and saturating it.

* * * * *

SINCE the notes on p. 96. *note*, and some other passages, were printed, I have had the satisfaction of seeing a paper lately read by Mr Cavendish before the Royal Society, and containing experiments which deeply affect some of the general theories mentioned as well in the dissertation as the notes. This paper, joined

joined to that which I have so frequently quoted, tends to clear up more obscurities in this branch of chemistry, than all the other facts and theories with which I am acquainted put together ; and with whatever modesty and simplicity his experiments may be related by the author, they ought to be accepted by those who have been perplexed by the endless doubts and difficulties that occur in all that has been written on aeriform substances, as great and important discoveries.

I HAVE already mentioned (p. 326.) the idea, that Mr Cavendish had thrown out on the nature of phlogisticated air, and observed, what was very obvious from the consideration of that philosopher's experiments, that the matter might be fully ascertained, by treating this elastic fluid with vital air. Mr Cavendish did not fail to pursue the path which thus lay open before him. He mixed phlogisticated and vital air together, and passed the electric spark through the mixture. In these trials, a diminution of bulk always was observed, insomuch that when five parts of vital air were added to three of common air, almost the whole disappeared. Moreover, by continuing his experiments, he discovered, that an acid liquor was produced, and that this acid was the nitrous. Thus, was his conjecture concerning the constitution of phlogisticated air fully confirmed ; and as, in the experiments already published, he had shown, that vital air is the same thing as water deprived of phlogiston ; so, in the present case, the addition of vital air is equivalent to the addition of water.

BUT

BUT his paper contains other experiments on the subject of aerial acid, that are equally interesting. Mr Kirwan, so far from admitting the validity of Mr Cavendish's objections to these experiments in which the elastic spark is made to pass through common or vital air, confined by a solution of litmus or of lime, retains them as the best arguments in favour of that opinion which he has espoused. It was therefore desirable to see how far experiment would countenance them.

WHEN the electric spark was taken in small portions of common air, confined by a solution of litmus, the liquor was turned red. This had been observed before ; but it was not before known, that, by continuing the sparks, the solution becomes quite clear and transparent ; so, however, it is : besides, half the air disappears, and, by the addition of lime-water, it is reduced $\frac{1}{5}$ more. It is, therefore, unquestionably true, that the litmus suffers a decomposition, loses its purple colour, and yields fixed air ; but there is nothing in any of these, or of the following experiments, which favours the opinion of air being diminished by means of phlogiston communicated by means of the electric spark.

WHEN lime-water was used instead of litmus, not the least cloud was observed ; the air was reduced to $\frac{2}{3}$ of its original bulk ; whereas, by phlogistication *,
it

* To shew the impropriety of the former erroneous phraseology, is always among the first consequences of new discoveries ; for, as the expression depends on the opinion that is formed of phænomen-

it loses but $\frac{1}{5}$. When the spark was taken in common or vital air not quite pure, no cloud was perceived, nor even when some aerial acid was introduced; but when, besides aerial acid, pure volatile alkali was added, a brown sediment immediately appeared. Hence, it is evident, as Mr Cavendish observes, that the calcareous earth must have been saturated by some acid, (*viz.* the nitrous), which was generated during the experiment; but, on the addition of pure volatile alkali, four powers came into action, the nitrous acid uniting with the volatile alkali, and the aerial acid with the lime. The brown colour of the sediment might be owing to some quicksilver being dissolved. It is, moreover, undeniable, that, if any aerial acid had been generated, it would have precipitated some of the earth, till a sufficient quantity of the other acid was produced to dissolve the whole.

THUS then it appears, that what in the opinion of its warmest maintainer are the most convincing proofs of the doctrine in question, are no proofs at all in its favour.

na, the former way of speaking will scarce ever be adapted to the new notions. By altering the meaning of the present phrase, it may perhaps be retained, since the vital part of the air does actually receive phlogiston; but it seems to me to express better, that the remaining elastic fluid has received an addition of phlogiston, by which its nature has been changed: whence, there will arise this inconvenience, that past writers will have used the same expression with one meaning, and future writers will use it with another. I think, therefore, that confusion will be best avoided, by substituting a new one.

favour. I never experienced greater surprise than on reading these experiments of Mr Cavendish. The precipitation of lime, in these circumstances, was so generally believed, that no one had scrupled to assume it as a certain ground of reasoning. Speculative men cannot learn, from a more striking instance, how necessary it is to begin with a strict examination of facts.

BUT whence arises the aerial acid that appears in those phlogistic processes in which animals are concerned? We find it not only in the air that has been respired by animals provided with lungs, but Mr Scheele detected it in air in which he had kept insects, and Mr Achard in common and vital air that had been injected into the cellular tissue of animals. If it does not proceed from any change of vital air, what remains but that it must be thrown off in substance? I would, therefore, propose this as a proper subject of experiment, not because I think it calculated to decide the chemical question concerning the constitution of the aerial acid, but because it is a curious physiological problem. I know but one fact that has any immediate connection with the solution of this problem, and that is contained in Mr Achard's paper on artificial emphysemas. He always found a large portion of aerial acid in inflammable air that had been forced into the cellular tissue of animals. If it was not contained beforehand in the inflammable air, and little or no common air was introduced along with it, which I think altogether unlikely, the result seems very much to favour the opinion

nion that supposes aerial acid to be an animal emanation.

I KNOW not whether I shall escape censure for dwelling so long, both here and before, on the question concerning the aerial acid ; but I presume, with some confidence, that no one who is capable of perceiving its extensive influence on the theory of so many chemical operations, will blame me with much severity. That the author of the dissertation considered it as a question of the utmost importance, appears from his accurate statement of the several theories, and of the objections that may be made to them. *Gaudemus interea*, says he, *quæstionem eo redactam fuisse, ut certitudo diu desiderari nequit* ; and accordingly, I think, we can now determine, with tolerable certainty, the merit of those theories, as well as explain the nature of phlogistic processes.

ON this subject, I have only to add, that in column 36. *vital air* ought to be placed above *nitrous acid*.

P. 188.] I FORGOT to observe, that ponderous earth had now been found, in more places than one, combined with aerial acid. The author himself received, a little while before his death, a specimen of this combination, which was transmitted to him from this country.

EXPLANATION

No. II

 \dot{V}_{Water}

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49
50

No. 1

In the DRY WAY.

[illegible]

To.

In the MOISTAY.

In the DRY WAY.

In the DRY WAY.					
31 Phlogiston	Phlogiston	Phlogiston	Phlogiston	Phlogiston	Phlogiston
32 Pure vegetable al. kali	Pure ponderous earth?	Pure ponderous earth?	Pure ponderous earth?	Pure ponderous earth?	Pure ponderous earth?
33 Pure fossil alkali	Pure vegetable al. kali	Pure vegetable al. kali	Pure vegetable al. kali	Pure vegetable al. kali	Pure vegetable al. kali
34 Pure pond. earth	Pure fossil alkali	Pure fossil alkali	Pure fossil alkali	Pure fossil alkali	Pure fossil alkali
35 Lime	Lime	Lime	Lime	Lime	Lime
36 Pure magnesia	Pure magnesia	Pure magnesia	Pure magnesia	Pure magnesia	Pure magnesia
37 Metallic calces	Metallic calces	Metallic calces	Metallic calces	Metallic calces	Metallic calces
38 Pure volatile alkali	Pure volatile alkali	Pure volatile alkali	Pure volatile alkali	Pure volatile alkali	Pure volatile alkali
39 Pure clay	Pure clay	Pure clay	Pure clay	Pure clay	Pure clay
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Acid

getable al-

93
15

Chemical Signs explained.

Acids.

1. + \odot nitric
2. + $\odot \frac{1}{4}$ — phlogisticated
3. + \odot nitrous
4. + $\odot \frac{1}{4}$ — phlogisticated
5. + \odot marine
6. + $\odot \frac{1}{4}$ — dephlogisticated
7. ∇ , *lique regia*
8. $\frac{1}{4} \nabla$ of *fluv*
9. $\odot \odot$ arsenic
10. + \triangle borac.
11. + \odot sugar
12. + ∇ tartar
13. + \oplus sorrel
14. + \subset lemon
15. + $\odot \odot$ benzoic
16. + \odot amber
17. + \odot sugar of milk
18. $\#$ uricous distilled
19. + \odot milk
20. + ∇ uric
21. + \odot fat
22. + $\frac{1}{4}$ of phosphorus
23. + $\frac{1}{4}$ perlatum
24. + $\frac{1}{4}$ Phosphorus blue

Alkalis.

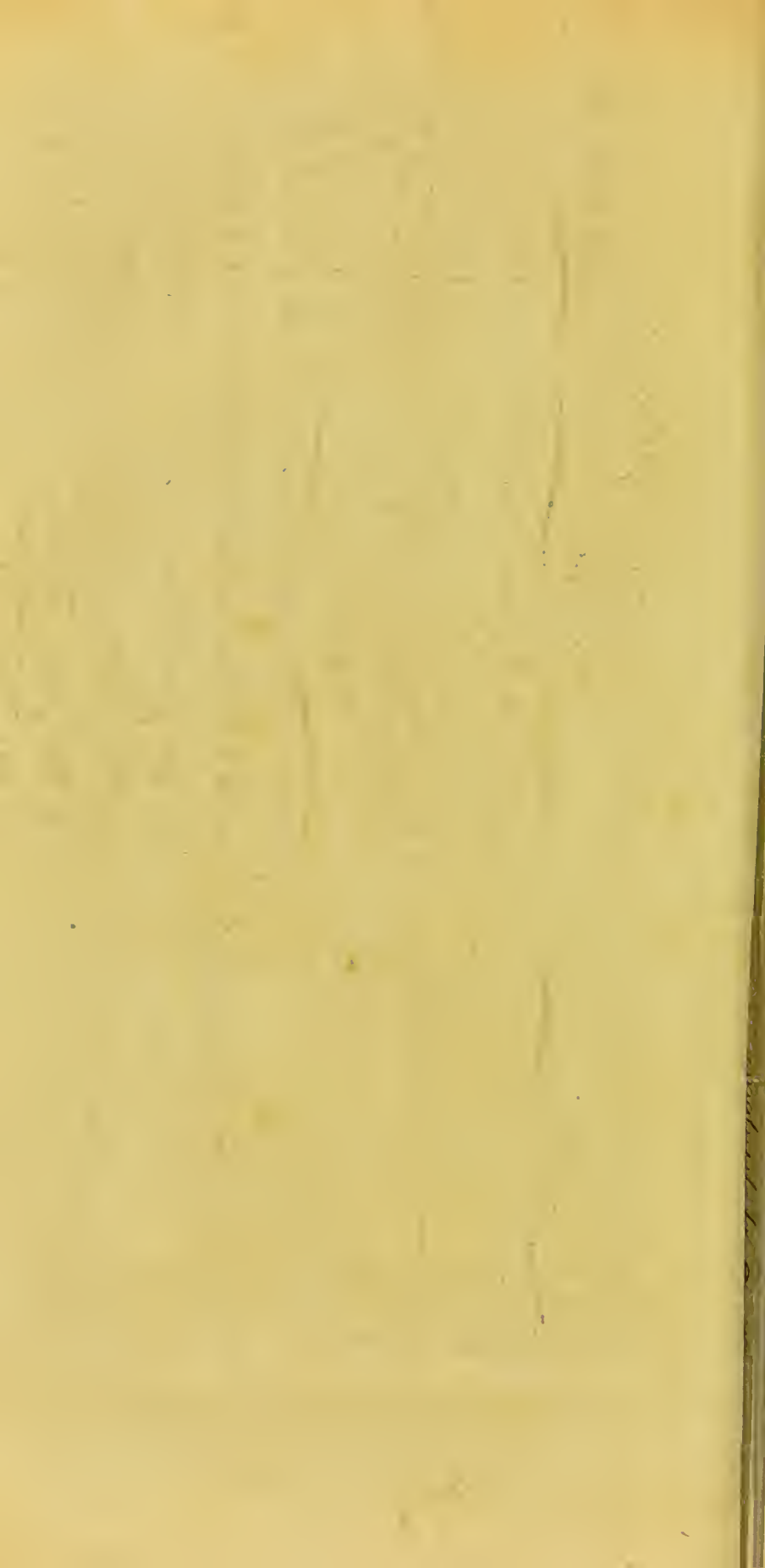
26. $\odot \nabla$ pure fixed vegetable
27. $\odot \nabla$ pure fixed mineral
28. $\odot \nabla$ pure volatile

Earths.

29. $\nabla \nabla$ pure ponderous
30. $\nabla \nabla$ pure calcareous fine
31. $\nabla \nabla$ pure magnesia
32. $\nabla \nabla$ pure argillaceous
33. $\nabla \nabla$ pure siliceous
34. ∇ water

Metallic Calces.

44. $\nabla \odot$ gold
45. $\nabla \odot$ platinum
46. $\nabla \odot$ silver
47. $\nabla \nabla$ mercury
48. $\nabla \nabla$ lead
49. $\nabla \nabla$ copper
50. $\nabla \nabla$ iron
51. $\nabla \nabla$ tin
52. $\nabla \nabla$ bismuth
53. $\nabla \nabla$ nickel
54. $\nabla \odot$ arsenic
55. $\nabla \nabla$ cobalt
56. $\nabla \odot$ zinc
57. $\nabla \odot$ antimony
58. $\nabla \nabla$ manganese
59. $\nabla \nabla$ siderite



[illegible]

[illegible]

EXPLANATION OF THE TABLE OF DOUBLE ELECTIVE ATTRACTIONS.

The first Forty take place in the HUMID WAY.

SCHEME 1. represents the decomposition of vitriolated vegetable alkali by ponderous earth, the vitriolated ponderous earth falling down insoluble, and the pure alkali remaining in the water.

SCHEME 2. shews that lime produces no such effect.

SCHEME 3. the decomposition of muriated fossil alkali or sea-salt by pure vegetable alkali, the new compound and the disengaged alkali both remaining in the liquor.

SCHEME 4. the decomposition of muriated lime (fixed ammoniac) by pure fossil alkali, the lime falling to the bottom.

SCHEME 5. Lime produces no change in a solution of muriated fixed alkali.

SCHEME 6. the decomposition of vitriolated magnesia (Epsom salt) by pure fixed alkali, the pure magnesia

A a

nesia

nesia falling to the bottom, and the new compound being dissolved.

SCHEME 7. the decomposition of corrosive sublimate by pure vegetable alkali, the mercurial calx falling down, and the new compound (digestive salt) being dissolved.

SCHEME 8. the decomposition of vitriolated iron (green vitriol) by lime, both the metallic calx and the new compound (gypsum) being precipitated.

SCHEMES 9. 10. 11. These schemes are admirably explained in the ninth section ; see also p. 170. The ninth represents the partial decomposition of vitriolated vegetable alkali by the nitrous acid : the tenth and eleventh that of nitre and digestive salt by the acid of tartar.

N. B. There is an error in the tenth Scheme of the original plate, which, as well as many others, is corrected in the Tables annexed to this Translation.

SCHEME 12. shews, that, on the contrary, the acid of tartar does not, in any respect, change muriated fossil alkali (sea-salt).

SCHEME 13. the decomposition of borax by nitrous acid, the new compound being dissolved, and the acid of borax appearing in a solid form.

SCHEME

SCHEME 14. the decomposition of vitriolated lime (gypsum) by acid of sugar, the saccharated lime falling down insoluble.

SCHEME 15. shews the decomposition of vitriolated magnesia by fluor acid : but see p. 187.

SCHEME 16. shews the decomposition of nitrated lime by vitriolic acid, the gypsum falling down.

SCHEME 17. shews the decomposition of white arsenic by dephlogisticated marine acid, the acid of arsenic appearing in a solid form.

SCHEME 18. shews that zinc precipitates silver from volatile alkali.

SCHEME 19. shews, that saline liver of sulphur is decomposed by the acetous acid, the sulphur being precipitated.

N. B. This Scheme includes many others, *a fortiori*.

SCHEME 20. shews the decomposition of calcareous liver of sulphur by vitriolic acid, both gypsum and sulphur falling down.

SCHEME 21. shews, that when solutions of vitriolated vegetable alkali and muriated lime are mixed, a double decomposition takes place, the digestive salt being dissolved, and the gypsum precipitated.

A a 2.

SCHEME

SCHEME 22. shews, that when vitriolated vegetable alkali in solution is added to muriated lead (*plumbum corneum*), a double decomposition takes place, the sea-salt being dissolved, and the vitriolated lead precipitated.

SCHEME 23. shews, that when muriated vegetable alkali and vitriolated lime are mixed together, no double decomposition takes place.

SCHEME 24. shews, that when vitriolated volatile alkali and muriated mercury are added together, a double decomposition takes place, the muriated volatile alkali (*sal ammoniac*) being dissolved, and the vitriolated mercury precipitated.

SCHEME 25. shews, that when nitrated *terra ponderosa* and oxalited volatile alkali are added together, an exchange of principles takes place, the oxalited earth falling down, and the nitrous ammoniac being dissolved.

SCHEME 26. shews the double decomposition of nitrated silver and common salt, the new neutral salt (nitrated fossil alkali) being dissolved, and the muriated silver (*argentum corneum*) falling down.

SCHEME 27. shews, that when tartar and nitrated mercury are mixed, they suffer a mutual decomposition,

tion, the nitre being dissolved, and the tartarized mercury precipitated.

SCHEME 28. shews, that when borax and nitrated mercury are mixed, a double decomposition takes place, the boraxated mercury falling down, and the nitrated fossil alkali dissolved.

SCHEME 29. shews, that when muriated magnesia and acetated silver are mixed, an exchange of principles takes place, the acetated magnesia being dissolved, and the muriated silver precipitated.

SCHEME 30. shews, that when vitriolated silver and muriated lead are mixed, a double exchange happens, and both muriated silver and vitriolated lead fall down insoluble.

SCHEME 31. shews, that when nitrated silver and muriated copper are mixed together, a double decomposition takes place, the nitrated copper being dissolved, and the muriated silver falling down.

SCHEME 32. shews, that when common salt and aerated vegetable alkali are mixed, a double exchange takes place, the digestive salt (muriated vegetable alkali) and the aerated fossil alkali being both dissolved.

SCHEME 33. shews, that when corrosive sublimate and aerated vegetable alkali are mixed, a double decomposition happens, the muriated vegetable alkali being dissolved, and the aerated mercury precipitated.

SCHEME 34. shews, that when nitrated lead and aerated fossil alkali are mixed, a double exchange is effected, the aerated lead falling down, and the nitrated fossil alkali being dissolved.

SCHEME 35. shews, that when vitriolated magnesia and aerated fixed alkali are mixed together, a double exchange takes place, the vitriolated alkali being dissolved, and the aerated magnesia falling down.

SCHEME 36. shews, that when muriated lime and aerated volatile alkali are mixed together, a double exchange takes place, the muriated volatile alkali (sal ammoniac) being dissolved, and the aerated lime falling down.

SCHEME 37. shews, that when aerated volatile alkali is added to a tincture of pure vegetable alkali, the vegetable alkali combines with the aerial acid, and falls down, while the volatile alkali combines with the alcohol.

SCHEME 38. shews, that when to nitrated silver copper is added, a double exchange takes place, the
phlogiston

phlogiston of the copper unites with the silver, which falls down, and the nitrous acid with the copper, which is dissolved.

SCHEME 39. shews, that if iron be added to copper dissolved in vitriolic acid, the phlogiston combines with the calx of copper, which is precipitated, and the vitriolic acid with the calx of iron, which is dissolved.

SCHEME 40. shews, that when saline liver of sulphur is mixed with acetated lead, a double exchange takes place, the lead falling down with the sulphur, and the acetated alkali being dissolved.

N. B. I cannot undertake to assign the reason why those cases of double attraction which are effected by the tinging acid, in combination with alkalis, and, as I suppose, with absorbent earths, at least with lime, are omitted in the present Table. The nature of the operation could not be unknown to the author, because he mentions it expressly, p. 302. I see, indeed, that he has omitted others that were known to him; nay, that he mentions in this very dissertation; whether it was that the reader could easily infer them from those cases that are represented in the Schemes, or whether they were doubtful, or of small importance in practice: but none of these considerations apply to the attractions in question; for they seem to be well ascertained as to their theory, and are undoubtedly of daily occurrence in the practice of chemistry.

It remains, that the deficiency be, in some measure, supplied; and I cannot do this better than by the following table, which I have extracted from the author's essay on metallic precipitates. The first column shews the colour of the precipitate; the second its quantity, from 100 grains of the regulus, dissolved in some acid menstruum.

	<i>Colour.</i>	<i>Weight.</i>
Gold,	yellow,	{ not perfectly precipitated.
Platina,		no precipitation.
Silver,	dark yellow,	145.
Mercury,	{ whitish at first; turns yellow when dry,	{ apt to be redif- solved.
Lead,	white.	
Copper,	{ greenish yellow; black- ish red when dry,	530.
Iron,	deep blue,	590.
Tin,	white,	250.
Bismuth,	yellowish,	180.
Nickle,	{ yellow; dark brown when dry,	250.
Arsenic,	white,	180.
Cobalt,	{ bluish red; brownish red when dry,	142.
Zinc,	{ white; citron yellow when dry,	495.
Antimony,	white,	138.
Manga- nese,	{ at first bluish, then yellowish blue, last- ly dark green.	

THE precipitates of tin, bismuth, nickle, antimony, and manganese, generally have their colours altered by the admixture of particles of Prussian blue, from the iron that is present. The ponderous earth is likewise precipitated by the combination of the tinging acid and alkali, (Preface to the *Sciagraphia*, and *Withering*, *ibid.*). Hence I imagined, that vitriolated ponderous earth might possibly be decomposed by the same powers. Having reduced a small quantity to a fine powder, I digested it in the sunshine for several hours in a solution of Prussian alkali, prepared according to Mr Scheele's method. After the supernatant liquor was poured off, and the residuum edulcorated, nitrous acid was added to it, which I supposed would expel the tinging acid from the earth, if any such union had taken place, and dissolve the latter ; but upon dropping some vitriolic acid into the nitrous, no precipitation was observable, which shews that it held no ponderous earth in solution. Whether this decomposition may be accomplished by applying a stronger heat, or following other methods, I know not.

THIS experiment led me to doubt, whether the Prussian alkali was capable of decomposing certain other compounds of acids and metals, besides the solution of platina. If any would resist its action, I thought vitriolated and muriated lead, and perhaps silver, to be the most likely ; particularly the former, from the conjecture that Bergman has thrown out in
the

the preface to his *Sciagraphia*, concerning the identity of the calx of lead and ponderous earth. I was, moreover, unable to recollect any thing satisfactory on this point in authors. Bergman himself, (*Opusc. Diff.* xxiii. § 5. letter E), says only, that “lead is
“precipitated of a white colour from its solution in
“nitrous acid by aerated and caustic fossil alkali, as
“well as by Prussian alkali.” I attempted, therefore, to satisfy myself, by repeating the foregoing experiment with vitriolated lead, except that I happened to use the acetous acid instead of the nitrous. But I now observed a white precipitate, both on the addition of vitriolic and muriatic acid, which seems to show, that a double decomposition had actually taken place. However, farther enquiry is necessary before any thing certain is determined; and I purpose to examine the several metallic salts above mentioned, when I have some tolerable convenience for making chemical experiments.

SCHEME 41. If vitriolated vegetable alkali be distilled with phosphoric acid, it will be decomposed; the vitriolic acid will be driven over, and the phosphorated alkali will remain at the bottom.

SCHEME 42. If common salt be subjected to distillation with nitrous acid, the marine acid will rise, and the nitrated fossil alkali remain in the retort.

SCHEME

SCHEME 43. If common salt be subjected to distillation with acid of arsenic, the marine acid will rise, and the arsenicated fossil alkali remain in the retort.

SCHEME 44. If muriated volatile alkali (sal ammoniac) be distilled with vitriolic acid, the marine acid will rise, and the vitriolated volatile alkali will likewise be sublimed.

SCHEME 45. If marine acid be distilled with the black calx of manganese, it will be dephlogisticated and rise, the white calx remaining fixed.

SCHEME 46. If sal ammoniac be treated with quicklime in distilling vessels, the pure volatile alkali will arise, and the muriated lime remain.

SCHEME 47. If sulphurated mercury (cinnabar) be subjected to distillation with iron, the mercury will rise in its metallic form, and the sulphurated iron remain.

SCHEME 48. If arsenicated fixed alkali be sublimed with inflammable matter, the arsenic will rise in a reguline form, and the alkali will remain?

SCHEME 49. If phosphorated volatile alkali be sublimed with inflammable matter, it will be decomposed, and the volatile alkali and phosphorus will both arise?

SCHEME

SCHEME 50. shews, that muriated lime is not decomposed by being exposed to distillation with volatile alkali.

SCHEME 51. shews, that fluorated lime is not decomposed by being exposed to fusion in a crucible with fixed vegetable alkali.

SCHEME 52. shews, that when an alloy of gold and silver is fused with sulphur, the sulphur combines with the silver, and leaves the gold free.

SCHEME 53. shews, that when sulphurated lead and iron are fused together, the sulphur unites with the iron, and leaves the lead free.

SCHEME 54. shews, that when copper is fused with a combination of saline liver of sulphur and silver, the copper unites with the liver of sulphur, and the silver is separated.

SCHEME 55. shews, that when nitre and muriatic acid are distilled together, the nitrous acid attracts the phlogiston of the marine acid, and quits the vegetable alkali.

SCHEME 56. shews, that when nitre and white arsenic are distilled together, the nitrous acid attracts

tracts the phlogiston, and rises, while the arsenical acid combines with the vegetable alkali.

SCHEME 57. shews, that when common salt and white arsenic are subjected to distillation together, no change is effected.

SCHEME 58. shews, that when corrosive sublimate is subjected to distillation with regulus of antimony, the calx of the mercury unites with the phlogiston of the antimony, and rises, while the muriatic acid combines with the calx of antimony, and rises in like manner.

SCHEME 59. shews, that when vitriolated vegetable alkali is exposed to sublimation with arsenicated volatile alkali, the vitriolic acid combines with the volatile alkali, and rises, while the arsenical acid combines with the vegetable alkali, and remains fixed.

SCHEME 60. shews, that when nitrated vegetable alkali and vitriolated volatile alkali are exposed to sublimation, the nitrous acid rises, combined with the volatile alkali, while the vitriolated vegetable alkali remains fixed.

SCHEME 61. shews, that when muriated fossil alkali and vitriolated mercury are sublimed together, the muriatic acid combines with the mercury, and
rises,

rises, while the vitriolated fossil alkali remains at the bottom.

SCHEME 62. shews, that when muriated volatile alkali and aerated lime are exposed to sublimation together, the aerial acid and volatile alkali rise combined, while the muriated lime remains fixed.

SCHEME 63. shews, that when aerated vegetable alkali and fluorated lime are fused together, the acid of fluor combines with the vegetable alkali, and the aerial acid with the lime, both remaining fixed.

SCHEME 64. shews, that when an alloy of gold and copper is fused with sulphurated antimony, the sulphur unites with the copper, and the gold with the antimony, both remaining fixed.

E M E N.

EMENDANDA.

- P. 41. l. 16. add *vitriolated tartar, nitre, and some other salts, are thus thrown down.*
- P. 66. l. the last, strike out *or not.*
- P. 68. l. 12. for *a* read *n.*
- P. 107. l. 13. for *acids*, read *metals.*
- P. 170. l. 5. after *manner*, insert *the acids of.*
- P. 182. l. 17. read the words, *which come next*, immediately after *sea-salt.*
- P. 236. l. 14. insert : between the two last quantities of the equation.
- P. 256. l. 17. after *specific*, add *beats.*

N. B. There are a few *literal errors*, which the context will at once direct the reader how to correct : And if there be a few wrong strokes yet remaining in TABLE III. they may be corrected from the corresponding Table of words.

